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Science Focus

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The Harvard astronomer
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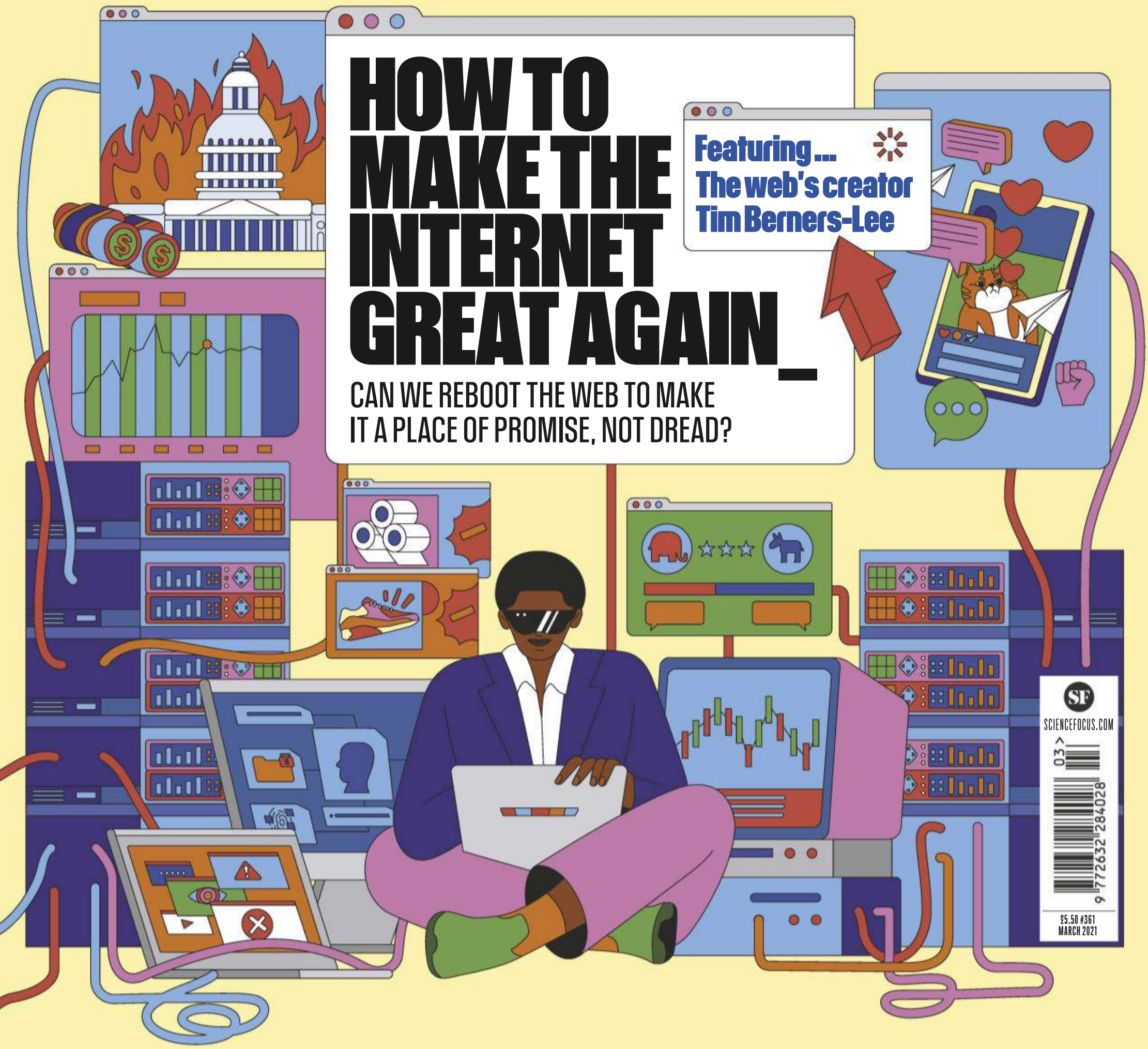

HOW TO MAKE THE INTERNET GREAT AGAIN_

CAN WE REBOOT THE WEB TO MAKE IT A PLACE OF PROMISE, NOT DREAD?

Featuring....
The web's creator
Tim Berners-Lee

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Diet
Can a pill help people lose weight?

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The women we don't talk about

Nature
Are rats claiming our empty cities?

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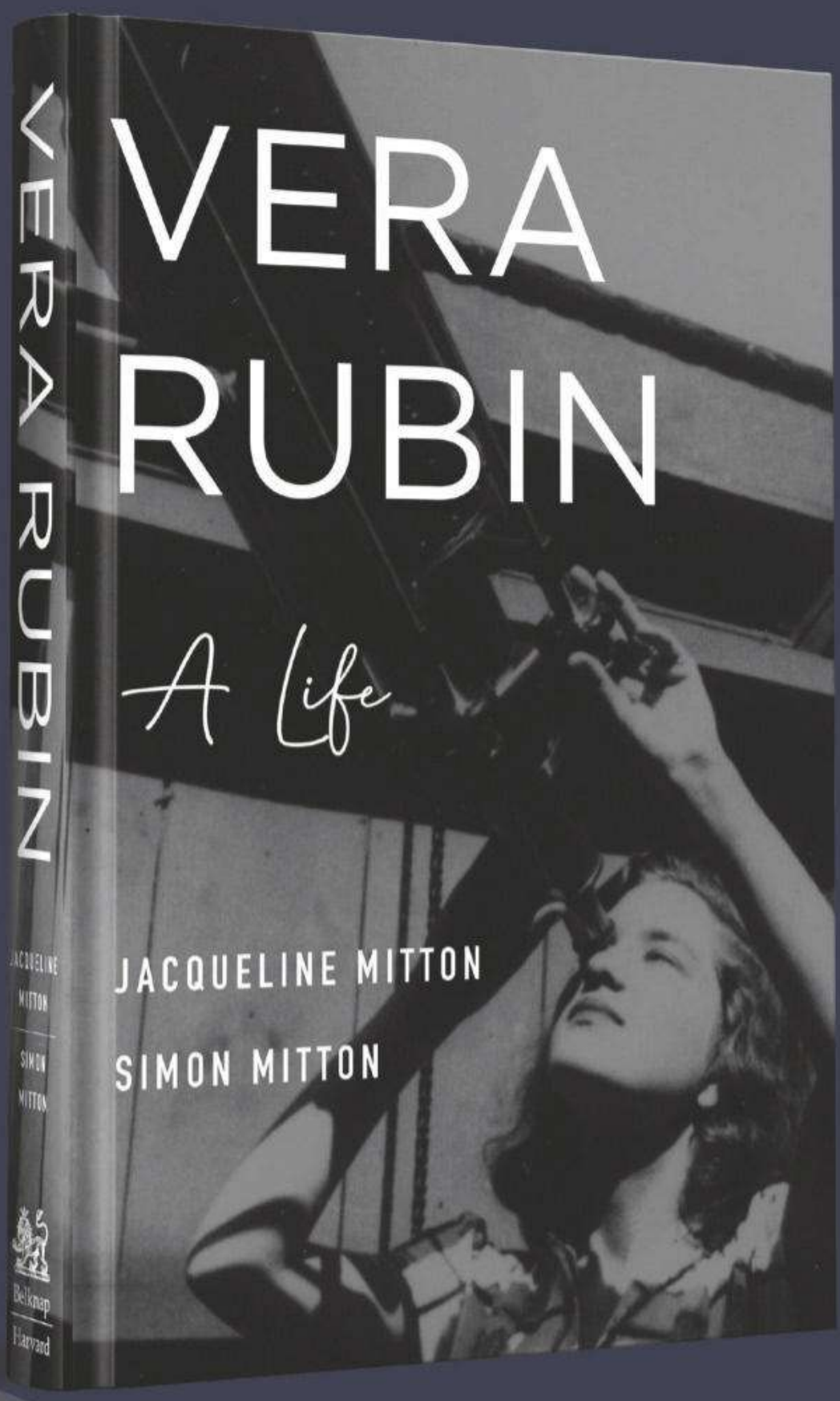

"This book firmly cements Rubin's place within the history of astronomy."

—Carolyn Collins Petersen, author of *The Discovery of the Universe*

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FROM THE EDITOR

I've lived most of my life online. From AOL to MSN Messenger to message boards to Zoom, the internet has given me the means to build relationships with strangers, friends and family that I couldn't even begin to put a price on. It has introduced me to art, culture and people that my parents would never have been exposed to, and I'm the richer for it.

But of late, the web is becoming a thing I peek at through the gaps in my fingers. Somewhere between countless data leaks, conspiracy theorists invading the Capitol and whatever Gwyneth Paltrow is selling these days, the web has started to lose its shine. As we seem to be reaching peak dissatisfaction with the web, we asked some of the leading voices in online culture – and the web's creator himself, Tim Berners-Lee – how we might build a better future for our digital lives. Head to p52 to find out how we can make the internet great again.

And as proof that the internet can be a force for good, in this issue I speak to Eliot Higgins, the founder of Bellingcat. Bellingcat is the people's intelligence agency, which uses information openly available online to investigate international crimes. They uncovered the culprits behind the Skripal poisonings, identified who shot down flight MH17 and proved that Bashar Al-Assad had used chemical weapons in Syria. And that's just the beginning – head to p42 to find out how they use the internet to hold power to account.

Enjoy the issue!

Daniel Bennett, Editor

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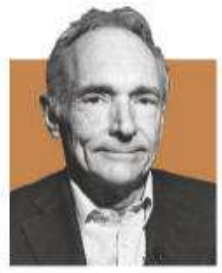

PROF SIR TIM BERNERS-LEE
Thirty years ago, Tim invented the World Wide Web. Now, fearing a digital dystopia, he's looking to upturn the system he created. →p54

DR JEREMY ROSSMAN
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CONTACT US

Advertising
daniel.long@immediate.co.uk
0117 300 8287
Letters for publication
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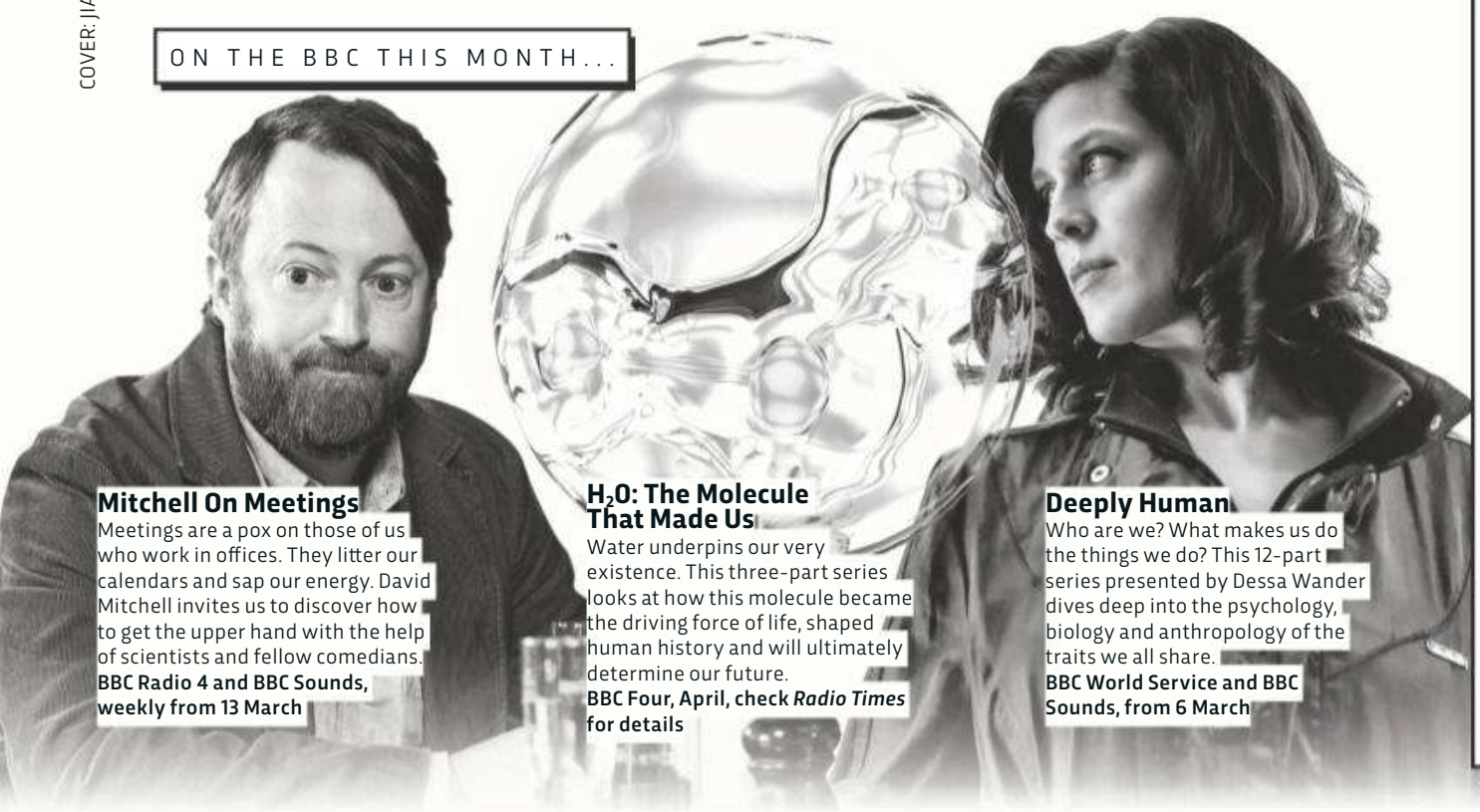

Mitchell On Meetings
Meetings are a pox on those of us who work in offices. They litter our calendars and sap our energy. David Mitchell invites us to discover how to get the upper hand with the help of scientists and fellow comedians.
BBC Radio 4 and BBC Sounds, weekly from 13 March

H_2O: The Molecule That Made Us
Water underpins our very existence. This three-part series looks at how this molecule became the driving force of life, shaped human history and will ultimately determine our future.
BBC Four, April, check *Radio Times* for details

Deeply Human
Who are we? What makes us do the things we do? This 12-part series presented by Dessa Wander dives deep into the psychology, biology and anthropology of the traits we all share.
BBC World Service and BBC Sounds, from 6 March

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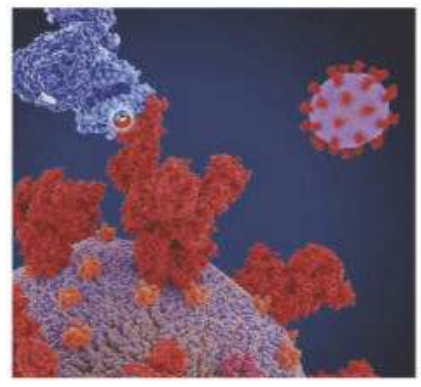

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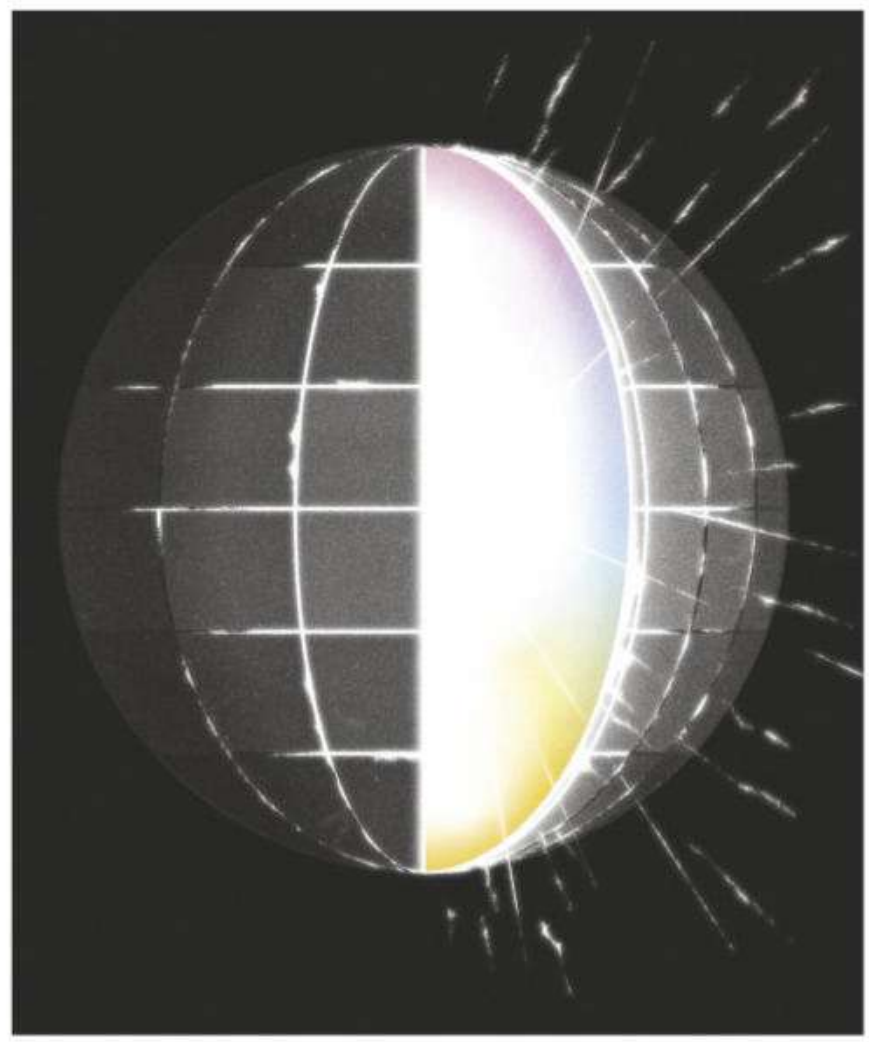

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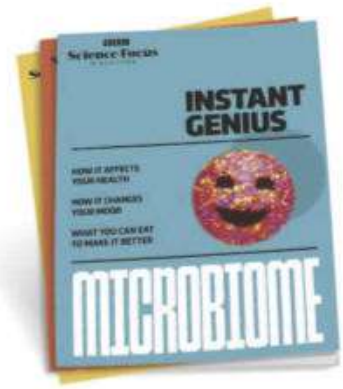

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

Family resemblance

I read your article about baboons' accents being analysed in the February issue of *Science Focus* (p28) and I thought that it was very interesting because I am learning Spanish and I realised that I do the same thing as the baboons when talking to the Spanish side of my family. I change the speed and the rhythm of my speech to match theirs. From this article I have really noticed how similar we are to baboons. Thank you, *Science Focus*.
Aris Norman, age 7 and 5/6

Well spotted, Aris. Some scientists call this behaviour 'the chameleon effect'. In humans, it's an attempt to show the person we're speaking to that we care. In baboons, it's possible that it serves the same function.
Daniel Bennett, editor

WRITE IN AND WIN!
The writer of next issue's *Letter Of The Month* wins a **Mophie powerstation wireless XL**. The 10,000mAh charger lets you wirelessly juice up your Qi-enabled devices with just the push of a button. Alternatively, you can use the superfast USB-C or USB-A connectors for wired charging. It's perfect for keeping your devices powered throughout the day. **zagg.com**

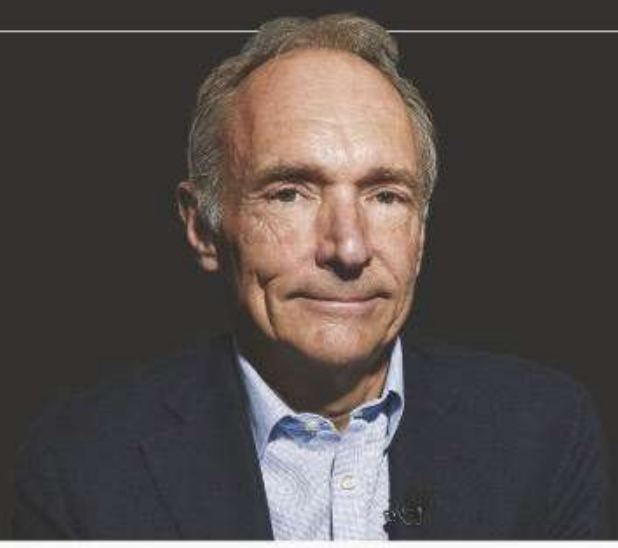
A shot in the dark

In 'Mysteries of the Universe' (January, p49) you suggest that "Maybe the Universe is filled with dark stars and dark planets and dark life!" I suggest this is extremely unlikely. The one thing that we can detect is the gravity dark matter has. If there was a planet in the Solar System made of dark matter, why has its effect on the orbits of the other planets not been detected? Our space probes often use the 'slingshot effect' of a planet's gravity on their journey. Have any of them ever had to take into account the gravity of a dark planet?

On the other hand, perhaps the reason we haven't observed the speculated ninth planet is because it's made of dark matter. Since both dark matter and atomic matter possess gravity, both types of celestial bodies must be attracted to each other. What happens when they collide? Has anyone ever observed this?
Barry Cash, Bristol

I wasn't saying there are dark planets in our Solar System – although, interestingly, Neptune was the 'dark matter' of its day, detected by its gravitational effect on Uranus before it was actually seen. For extrasolar planets, we infer their existence generally from their gravitational tug on their parent

Exoplanets are probably made of ordinary matter, but there's a possibility they are made of dark matter



"IN GENERAL, THE WEB HAS BEEN INCREDIBLY GOOD AT DEMONSTRATING THAT LOVELY THOUGH THE WALLED GARDEN MIGHT SEEM, THE OUTSIDE JUNGLE IS MORE VALUABLE. "

PROF SIR TIM BERNERS-LEE, P56

star. We don't see them directly. We can deduce only their mass. We have no idea what kind of mass that is. It could be ordinary matter (which is the most likely possibility), but dark matter can't be ruled out.
Marcus Chown, astrophysicist

Teacher, teacher

I'd like to present the other side of the coin to Aleks Krotoski's comment on going back to school (September, p58). She refers to the trauma in parents facing the pandemic and looking forward to returning their children to school, where teachers take over responsibility of education. But I found educating my six-year-old during the lockdown was a positive experience. I developed an understanding of how to provide a formal education, learned the curriculum, became more creative to occupy my boy's time and came to appreciate the role of the teacher.
Grant Davies

Faking it

As someone who used to work on the spiritual phone lines many years ago, I would argue that what 'spiritualists' are actually hearing is the money (February, p24). I was especially good at the 'spiritual' side of the job, and the longer people stayed on the phone, the more I got paid. When people are unhappy they give away all sorts of information and will grasp any 'messages' they are given by a third party to make it fit their own narrative. I had the knack of listening to callers' sorrows and telling them what they wanted to hear, including messages from dead relatives that were totally fabricated. I probably could have gone on to make a lot of money, but my own inner voice told me it was morally wrong. The 'spiritualists' in Dr Powell's study are only absorbed in trying to appear genuine, both to their clients and to the researchers.
Carole Ludlow Mooney, Ashton-under-Lyne

NASA, GETTY IMAGES X2

Could matter pop in and our of existence, pondered Tom Moon over his breakfast

Snap, crackle... and pop!

While eating my breakfast waffles and reading the January issue of *BBC Science Focus*, a theory relating to the expansion of the Universe came to mind. What if quantum theory is correct and matter (or parts of matter) do briefly pop in and out of existence, but only do so where no matter already exists in the vacuum of space?

This would explain the expanding Universe and give the illusion that gravity was working to push bodies together when, in fact, it would be the subatomic particles and the space they inhabit causing the huge bodies to come together. They could pop back out of existence but leave the space they inhabited behind.

Just because energy and matter can't be created inside our Universe, it doesn't mean that energy or matter couldn't be slipping through from parallel universes. Just the start of a theory for someone with more expertise to ponder.
Tom Moon, via email

THE TEAM

EDITORIAL
Editor Daniel Bennett
Managing editor Alice Lipscombe-Southwell
Commissioning editor Jason Goodyer
Staff writer Thomas Ling
Editorial assistant Amy Barrett
Online assistant Sara Rigby

ART
Art editor Joe Eden
Picture editor James Cutmore

CONTRIBUTORS
Scott Balmer, Rob Banino, Abigail Beall, Hayley Bennett, Peter Bentley, Dan Bright, Steve Brusatte, Steve Boswell, John Butterworth, Anson Chan, Stuart Clark, Emma Davies, Alexandra Franklin-Cheung, Alastair Gunn, Matt Harrison Clough, Brenna Hassett, Ben Holder, Adam Hylands, Christian Jarrett, Aleks Krotoski, Pete Lawrence, Nish Manek, Michael Mosley, Stephanie Organ, Helen Pilcher, Jason Raish, Jeremy Rossman, Thomas Sanders, Moya Sarner, Helen Scales, Kyle Smart, Holly Spanner, Luis Villazon, Jiaqi Wang.

ADVERTISING & MARKETING
Group advertising manager Tom Drew
Business development manager Dan Long
daniel.long@immediate.co.uk
Newstrade manager Helen Seymour
Subscriptions director Jacky Perales-Morris
Direct marketing manager Kellie Lane

MOBILE
Head of apps and digital edition marketing Mark Summerton

INSERTS
Laurence Robertson 00353 876 902208

LICENSING & SYNDICATION
Director of licensing and syndication Tim Hudson
International partners manager Anna Brown

PRODUCTION
Production director Sarah Powell
Production coordinator Georgia Tolley
Ad services manager Paul Thornton
Ad designer Julia Young

PUBLISHING
Publisher Andrew Davies
Group managing director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, editorial review boards Nicholas Brett
Managing director, consumer products and licensing Stephen Davies
Director, magazines Mandy Thwaites
Compliance manager Cameron McEwan
UK publishing coordinator Eva Abramik
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EDITORIAL COMPLAINTS
editorialcomplaints@immediate.co.uk

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EYE OPENER

In full bloom

FRIEDRICHSHAFEN, GERMANY

This is Europe's first five-metre-diameter deployable reflector for radar satellites. It's been designed to be able to send and receive higher resolution signals for better observations of Earth. Built by Airbus, it's currently scheduled for launch in 2022.

It's special because it's made from a semi-rigid material. Normally, dishes as big or bigger than this have to be flexible so they can be folded up to fit inside a rocket. It's like putting a ship in a bottle, except the ship is a satellite and the bottle is the rocket carrying it into space. Once the rocket reaches orbit, the satellite is deployed and unfolded, and if all goes according to plan it begins transmitting and receiving signals.

The trouble is, satellite dishes work better if they're rigid. Hence Airbus has developed this one, which is too rigid to fold in the traditional sense but is just flexible enough to close like a flower so it can be stowed for launch.

SANDRA WALTHER/AIRBUS

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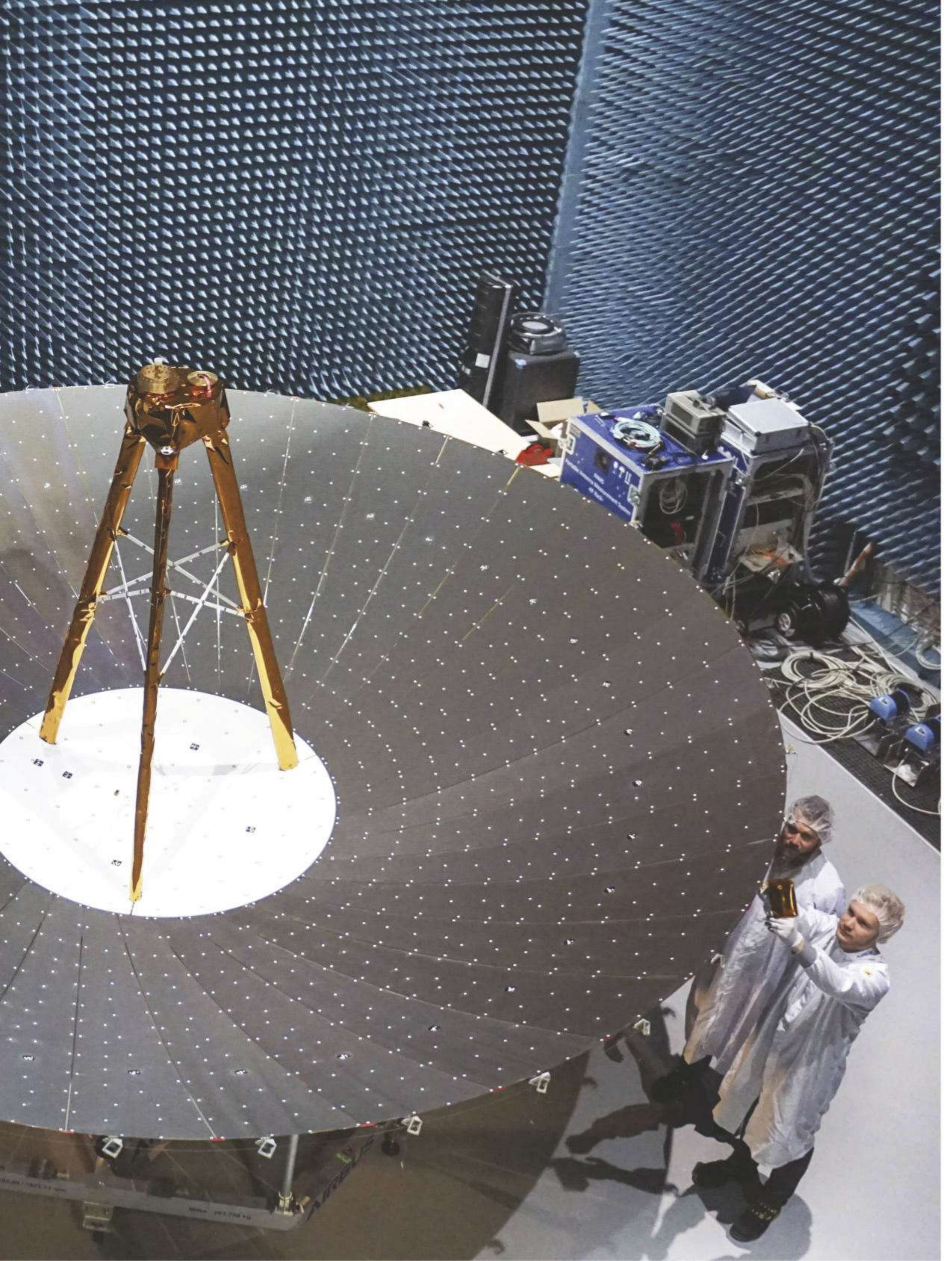

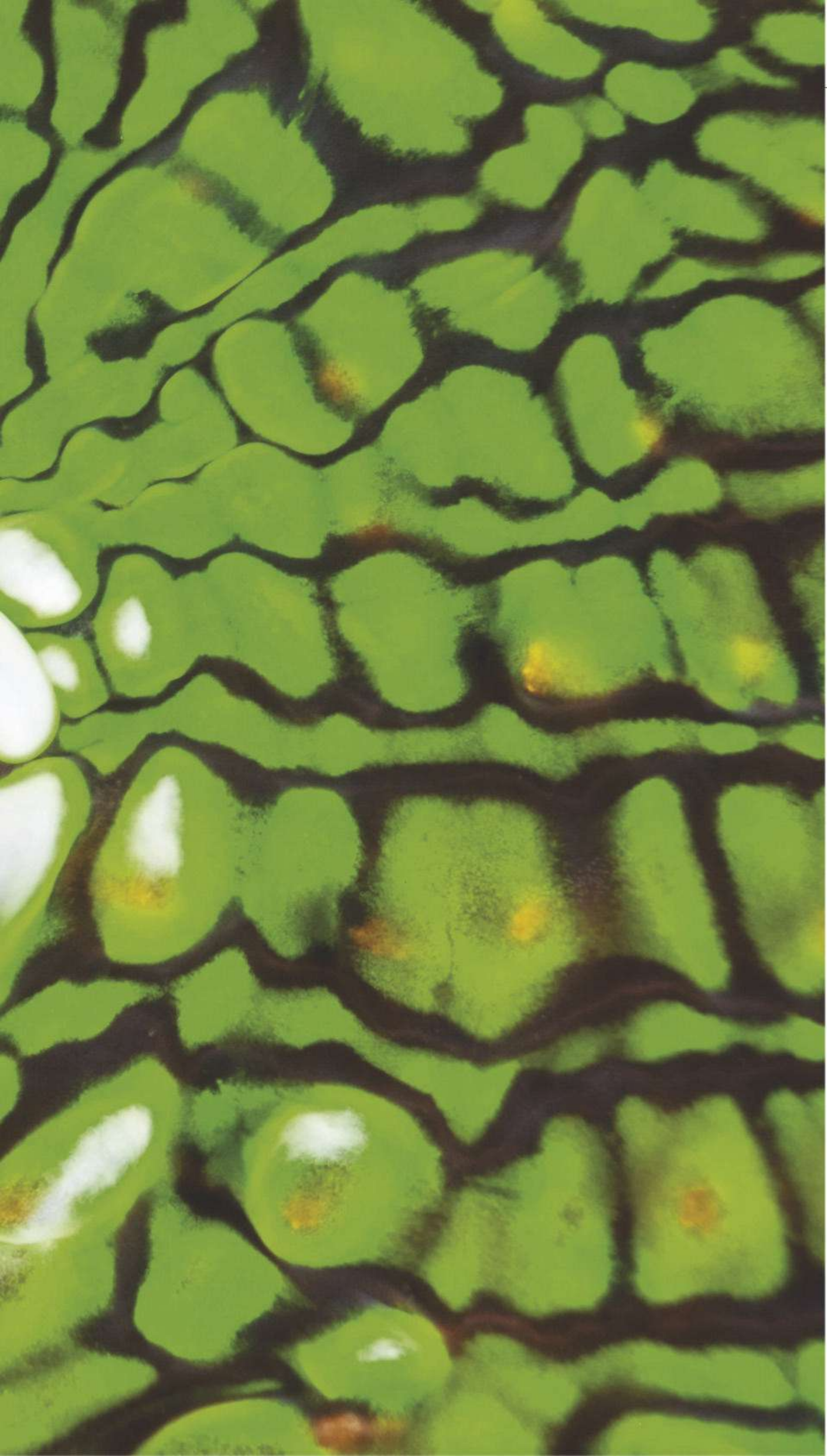

EYE OPENER

Say ‘ahhh...’

GARDENS OF THE QUEEN NATIONAL PARK, CUBA

The mouth at the centre of this somewhat hallucinatory image belongs to an artichoke coral (*Scolymia cubensis*). They’re solitary creatures that grow into concave discs that can reach up to 10cm in diameter and vary in colour from light brown to deep red – or in the case of this one, a seemingly radioactive shade of green.

This coral was so vivid that the photographer spotted it easily, despite it sitting on a reef 20 metres below the surface. It was found in a marine reserve 97 kilometres off the southeast coast of Cuba.

If it wasn’t eye-catching enough already, artichoke coral becomes even more of a sight to behold when the Sun goes down. After nightfall, tentacles emerge from the mouth and extend into the water to catch plankton floating by.

Its mouth has another important role to play, though. As the coral is flat, sediment can collect on its disc, but by undulating its mouth, the coral can shake any detritus off.

SHANE GROSS/NATUREPL.COM

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EYE OPENER

Pulling faces

HONG KONG, CHINA

Don't let the grimace put you off; Sophia is here to help. Sophia is one of the robots being produced by Hanson Robotics to lend a hand during the pandemic, whether it's by taking your temperature or keeping you company. On the inside is an AI system that can respond with conversational speech. While on the outside are articulated limbs to reflect our body language, and a head capable of complex facial expressions.

"Social robots, like Sophia, that read and express facial emotions, are more tolerable [to humans] as they tend to react more as we expect a living creature to react," says Dr Peter J Bentley, author of *10 Short Lessons In Artificial Intelligence And Robotics*. "Today's environment, where we find ourselves starved of company, yet nervous of human contact, may make this form of robot more popular. Their use could help the general public follow directions and obey safety rules without putting people at risk."

REUTERS

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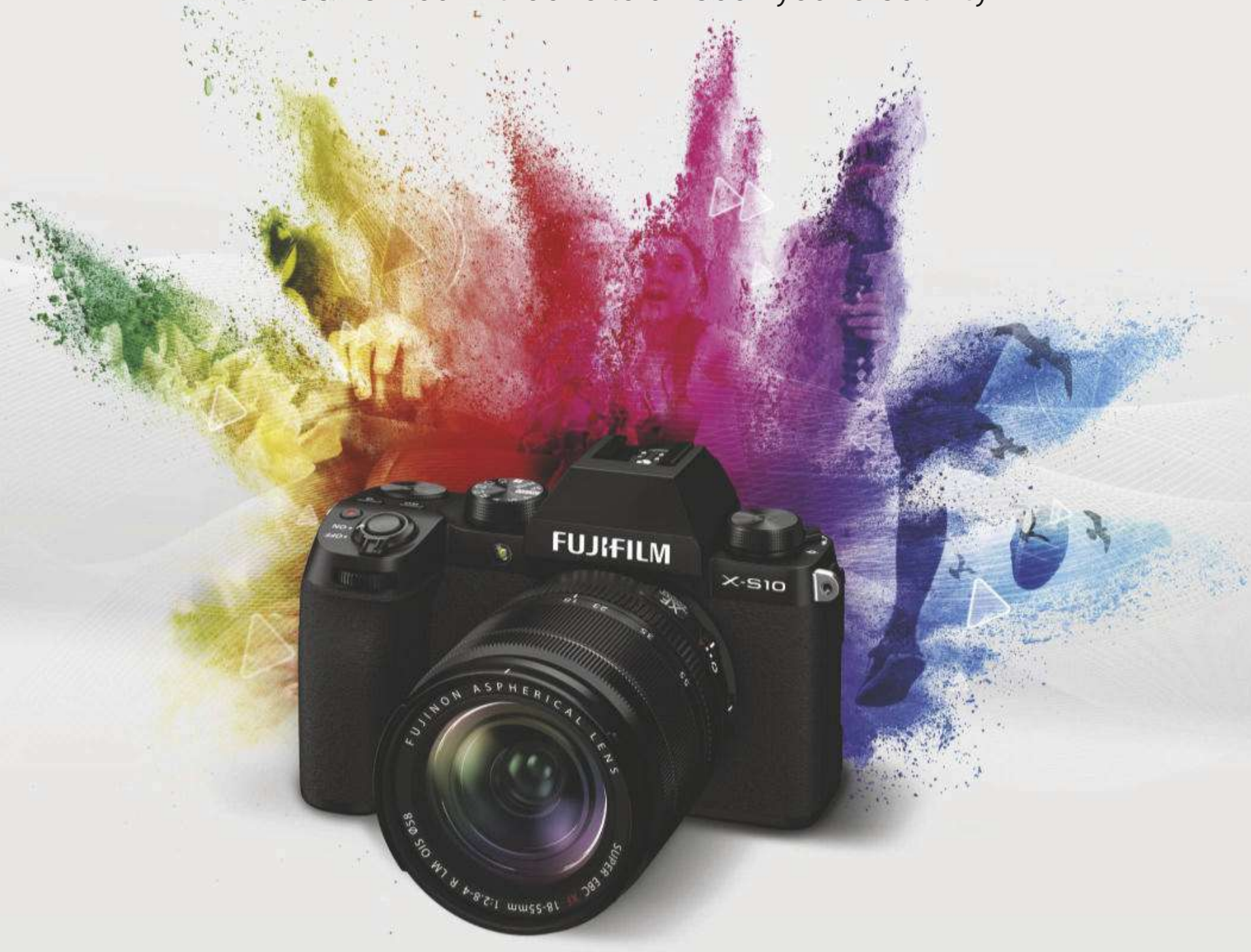

"X-S10 makes a lot of sense for a lot of people"

-Photography Blog

"If you own an APS-C DSLR and want to switch to a smaller, lighter mirrorless system, quite simply this is the camera for you."

-Amateur Photographer

"The X-S10 is an easy camera to recommend for photographers of all kinds"

-DP Review

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BRAIN MAPPING
Brain development captured in living worm p17

PORKNITE
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POPEYE WAS RIGHT
Spinach could protect astronauts from radiation p19

GET TO MARS
First pictures from the new missions to the Red Planet p20

DISCOVERIES

ENDANGERED FERRET CLONED FROM SPECIMEN FROZEN FOR 30 YEARS

The healthy young kit may help to save the species from extinction

USFWS NATIONAL BLACK FOOTED FERRET CONSERVATION CENTER

Poisonous sperm One type of sperm wins 99 per cent of the time p22 **Anyfin is possible** A single genetic change turned a fish's fins into limbs p23 **Aliens after all?** Why we should keep an open mind about 'Oumuamua p24

Ben Novak, a lead scientist involved with the project, holds Elizabeth Ann. She is three weeks old in this image

The future of the endangered black-footed ferret looks a little brighter, following the birth of this adorable little bundle of teeth and fur.

Named Elizabeth Ann, the tiny kit was born on 10 December 2020 at the National Black-Footed Ferret Conservation Center (NBFFCC) in Colorado, thanks to the conservation efforts of a collaboration led by the U.S. Fish and Wildlife Service.

Her birth marks the first time that an endangered species native to the US has been successfully cloned.

"Although this research is preliminary, it is the first cloning of a native endangered species in North America, and it provides a promising tool for continued efforts to conserve the black-footed ferret," explained Noreen Walsh, director of the U.S. Fish and Wildlife Service's Mountain-Prairie Region."Maintaining and increasing wild populations and suitable habitat continues to be essential for black-footed ferret recovery and will remain a priority for the service."

Once thought to be extinct and currently listed as an endangered species, black-footed ferrets were brought back from the brink after a Wyoming rancher discovered a small colony of the animals hunkered down on his land in 1981.

The Wyoming Game & Fish Department then captured some of the animals to begin a breeding programme in an attempt to recover the species.

"This is the first cloning of a native endangered species in North America"

Today, all 350 black-footed ferrets are descended from just seven individuals, giving rise to significant genetic challenges in fully recovering the species. Without an appropriate amount of genetic diversity, a species quickly becomes more susceptible to diseases and genetic abnormalities, as well as suffering from decreased fertility rates and a reduced ability to adapt to changing environments.

Elizabeth Ann was cloned from the genetic material of a black-footed ferret named Willa that has been kept in storage at San Diego Zoo Global's Frozen Zoo since 1988.

Crucially, Willa has no currently living descendants, making her genes significantly different from the offspring of the seven founding ferrets. This means that if Elizabeth Ann successfully mates and reproduces, she could introduce new genetic diversity to the species.

A team from US cloning experts ViaGen Pets & Equine produced cloned embryos from the frozen cell line and implanted them into a domestic ferret surrogate.

The surrogate mother was then transferred from ViaGen Pets & Equine to the NBFFCC where she successfully gave birth to Elizabeth Ann.

"San Diego Zoo Global's Frozen Zoo was created more than 40 years ago with the hope that it would provide solutions to future conservation challenges," said Oliver Ryder, director of conservation genetics at San Diego Zoo Global. "We are delighted that we have been able to cryobank and, years later, provide viable cell cultures for this groundbreaking project."

Elizabeth Ann and her surrogate mother will now live at the NBFFCC, separated from the other breeding black-footed ferrets, as further research is completed. The team are working to produce more black-footed ferret clones in the coming months as part of continuing research efforts.

NEUROSCIENCE

Process of brain development viewed in a living animal for the first time

Studying the developing brain of a living animal has long been thought to be almost impossible, thanks to the intricate tangle of neurons and vast labyrinth-like paths of connections that need to be imaged in real time.

Now, researchers at the Yale School of Medicine have used computing and microscopy techniques to view this previously impenetrable process as it unfolded in a living nematode worm, *Caenorhabditis elegans*. These worms are often used in research as they share key molecular and genetic characteristics with humans, despite their relatively simple biology.

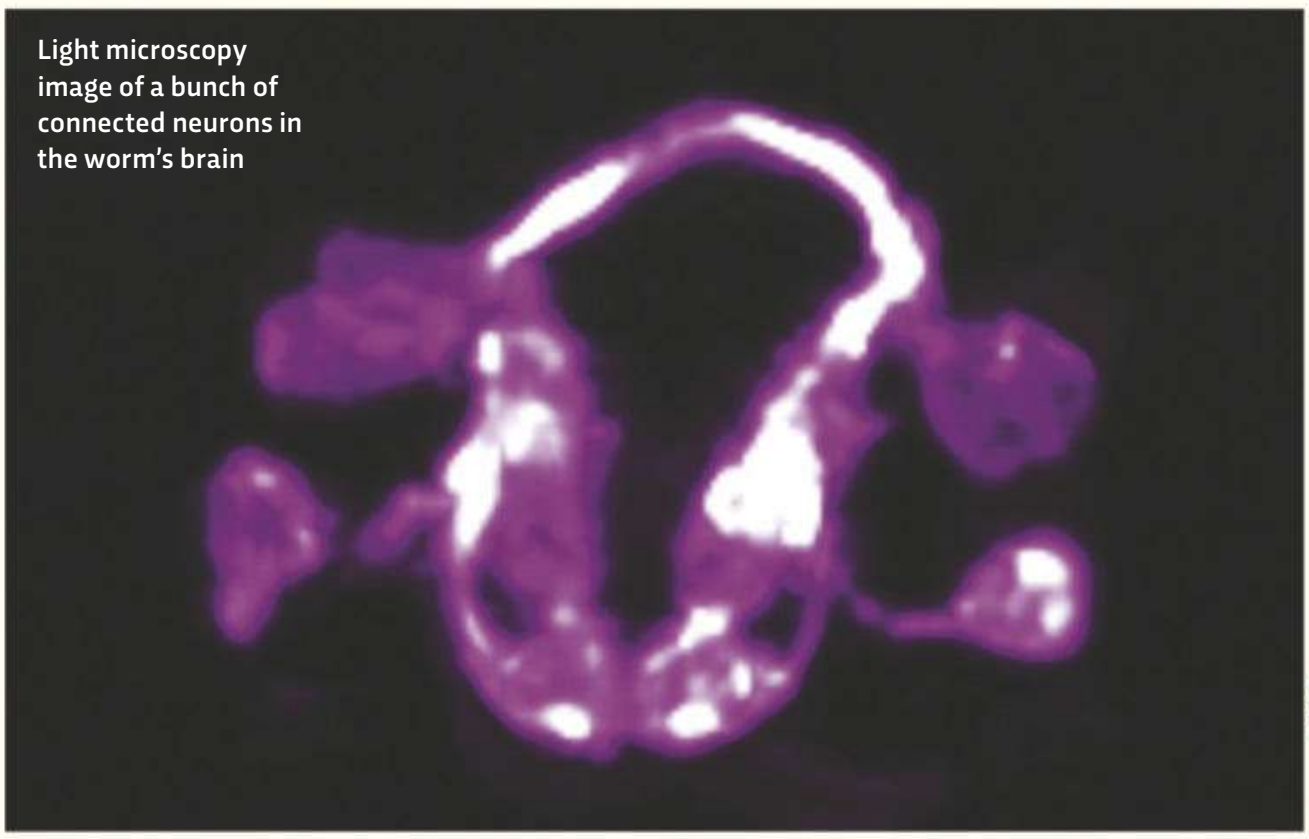
"Before, we were able to study single cells, or small groups of cells, in the context of the living *C. elegans*, and for relatively short periods of time," said lead researcher Dr Mark Moyle, an associate research scientist in neuroscience at Yale School of Medicine. "It has been a breathtaking experience to now be able to watch development unfold for hours, across the entire brain of the organism, and visualise this highly orchestrated dance," he added.

The researchers found that neuronal processes in the worm's brain are organised into layers, each containing specific circuits that are linked to distinct behaviours.

By using high-resolution light sheet microscopy, they were able to track the paths of single cells over the course of the organism's development, allowing them to investigate how these cells help choreograph the assembly of the brain.

The brain is organised like a city such as London, they say, with areas like the City of London or Soho organised to carry out the specific functions of finance and entertainment.

"When you see the architecture, you realise that all this knowledge that was out there about the animal's behaviours has a home in the structure of the brain," said co-author Prof Daniel Colón-Ramos, the Dorys McConnell Duberg Professor of Neuroscience and Cell Biology. "Suddenly you see how the city fits together and you understand the relationships between the neighbourhoods."



Light microscopy image of a bunch of connected neurons in the worm's brain

USFWS NATIONAL BLACK-FOOTED FERRET CONSERVATION CENTER, YALE UNIVERSITY ILLUSTRATIONS: KYLE SMART

CHIP LOVERS
No more soggy fries! Researchers in California have created a stick-on patch called SAVRpak that absorbs the condensation from takeaway food containers, keeping their contents crispier.

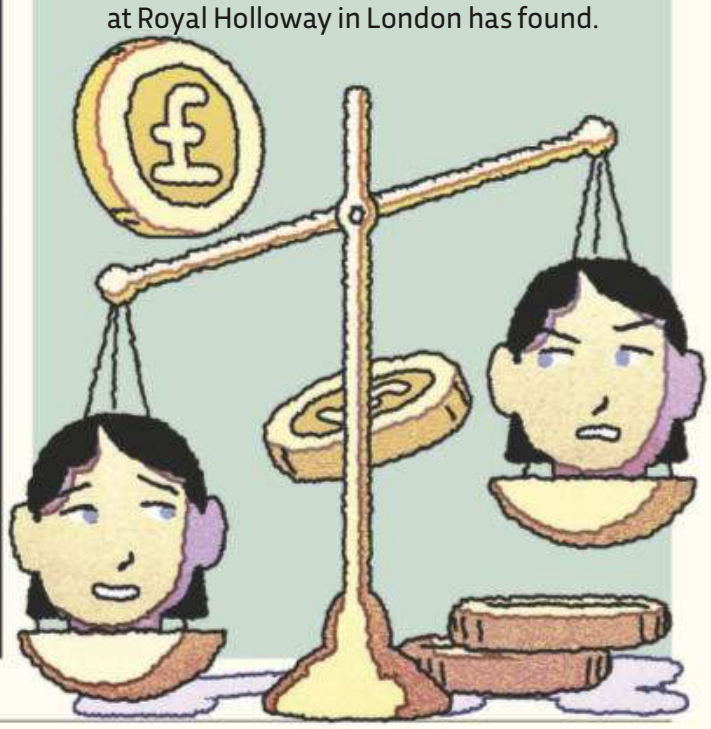
COLD 'SUPER RESISTORS'
Up to a fifth of people have 'super resilience' to cold temperatures, thanks to a lack of alpha-actinin-3 protein in their muscle fibres. This allows them to regulate their body heat more efficiently, a study at Sweden's Karolinska Institute has found.

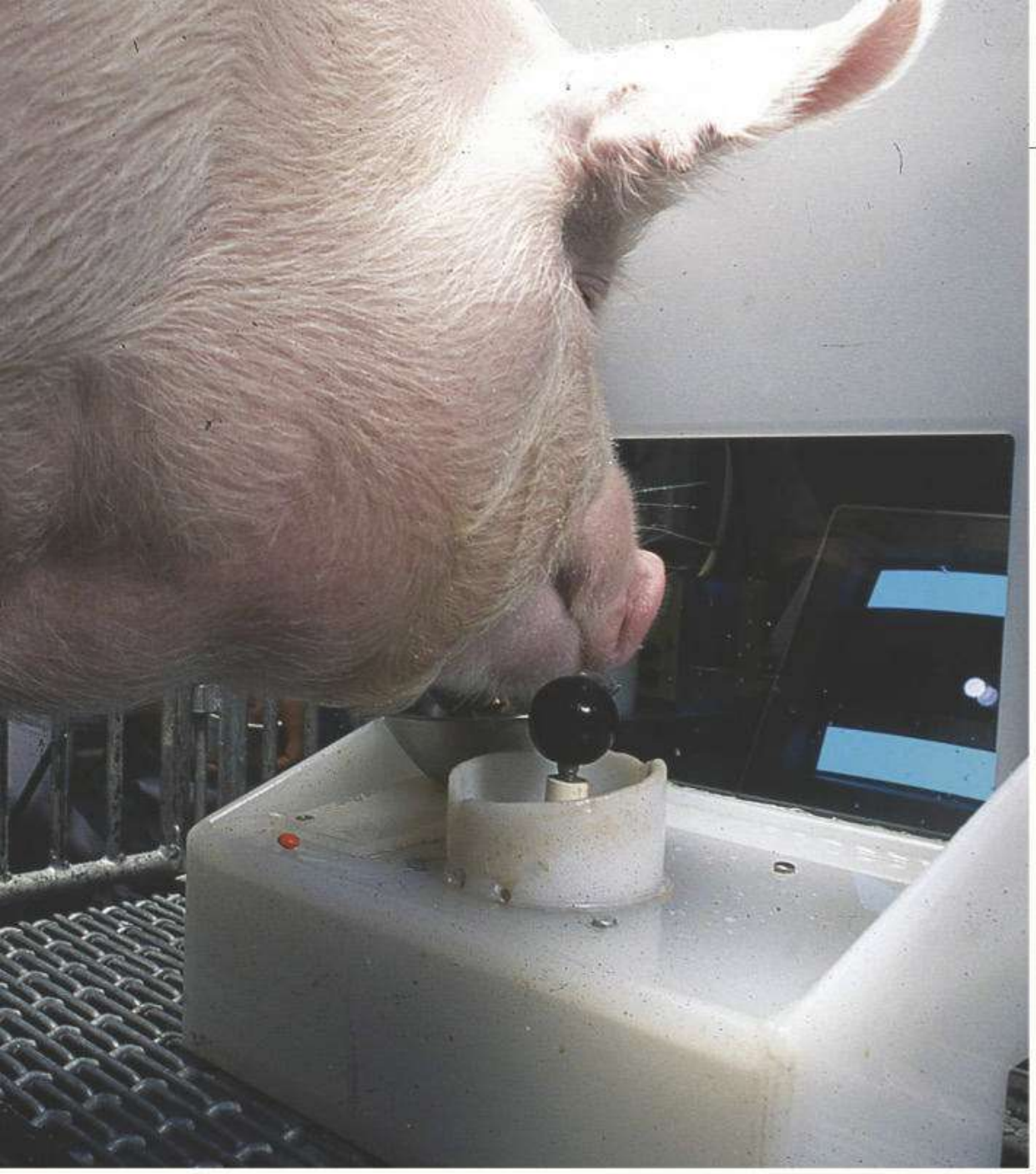
Good month

Bad month

COOKERY SHOW FANS
Gordon Ramsay? Nigella Lawson? Matty Matheson? Whoever your favourite celeb chef is, it seems that watching them prepare their tasty morsels may make us feel hungrier and more likely to overeat, a study at the University of Surrey has found.

THE FROWNY FACED
Those with expressions that appear angry, disgusted or irritated are more likely to be judged as being less wealthy than those with more upbeat expressions, a study carried out at Royal Holloway in London has found.





Porknite: pigs have mental capacity to play video games, study suggests

Pigs understand simple video games, and can move a joystick with their snout

Time to load up *Ham Theft Auto*: new research indicates pigs possess the mental capacity to play video games. The study, published in *Frontiers In Psychology*, tested the ability of four hogs (Hamlet, Omelette, Ebony and Ivory) to play a simple joystick game with their snouts, moving a cursor to four targets on the screen. Although the animals didn't demonstrate the dexterity to win a round of *Fortnite* any time soon, they did show a conceptual understanding of this rudimentary game.

Performing well above chance, the pigs appeared to recognise the movement of the cursor was controlled by the joystick. The fact they did so well despite a lack of opposable thumbs is "remarkable", according to the researchers.

"It is no small feat for an animal to grasp the concept that the behaviour they are performing is having an effect elsewhere. That pigs can do this to any degree should give us pause as to what else they are capable of learning and how such learning may impact them," said Purdue University's Dr Candace Croney, the study's lead author.

Researchers also noted that while the pigs could be taught to play the game using food as positive reinforcement, they also responded well to social cues. In fact, when the game was made more challenging and the pigs became reluctant to engage, "only verbal encouragement by the experimenter" would see training resume.

These findings are the latest to highlight the intelligence of pigs. Not only have they been shown to use mirrors to find hidden food in an enclosure, but studies have also demonstrated how hogs can be taught to 'come' and 'sit' after verbal commands.

"As with any sentient beings, how we interact with pigs and what we do to them impacts and matters to them," Croney said. "We therefore have an ethical obligation to understand how pigs acquire information, and what they are capable of learning and remembering, because it ultimately has implications for how they perceive their interactions with us and their environments."

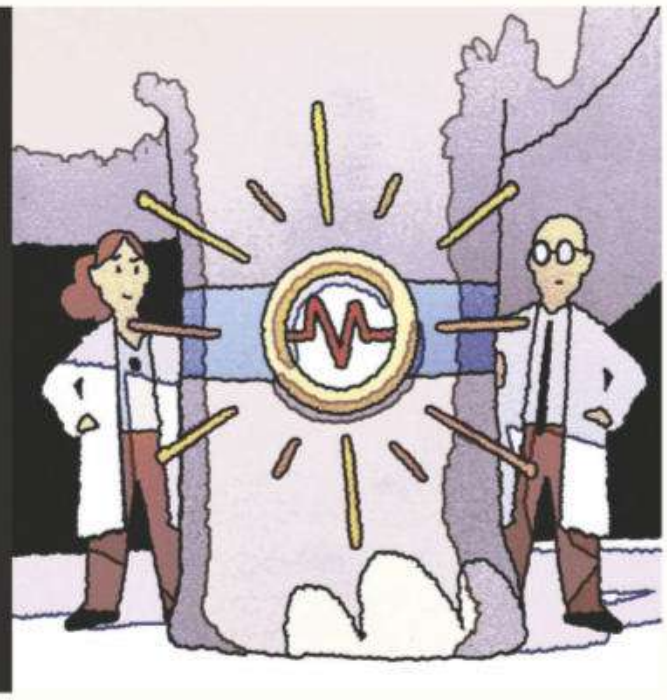
They did what?

Elephants fitted with fitness watches

WHAT DID THEY DO?
Researchers from the University of Alabama at Birmingham, US, fitted fitness trackers to the front legs of a herd of captive Asian elephants and monitored their activity levels. They also took measurements of the animals' body fat percentages and fertility levels.

WHY DID THEY DO THAT?
Many researchers believe that a large proportion of the elephants living in captivity are overweight and are concerned that this may be contributing to their low birth rates. Until now, no one had actually investigated the relationship between elephants' body fat and fertility.

WHAT DID THEY FIND?
The trackers revealed that the elephants were walking similar distances to wild animals. They also found that body fat percentages ranged from 2 per cent to 25 per cent. The male elephants averaged around 8.5 per cent, and females 10 per cent. (Healthy humans range between 6 and 31 per cent.) Among the female elephants, it was the leaner animals that were more likely to be infertile, not those carrying more body fat. This effect may be similar to the disrupted fertility cycles found in underweight humans, the researchers say.



ESTON MARTZ/PENN SYLVANIA STATE UNIVERSITY, GETTY IMAGES ILLUSTRATION: KYLE SMART

Long-distance space travel will expose astronauts to dangerous levels of radiation

Eating spinach could protect astronauts from space radiation

One of the biggest barriers to long-distance space travel is how to protect astronauts from the damaging effects of space radiation. Cosmic rays and proton storms from the Sun expose spacefarers to dangerous levels of radiation that the human body has not evolved to handle.

However, an antioxidant-rich diet could go some way to protecting cardiovascular health in space.

"If we want to see human long-distance space travel, we need to understand the impact of space-induced disease and how to protect our bodies from it," said Dr Jesper Hjortnaes of the Leiden University Medical Center in the Netherlands.

> **"We need to understand space-induced disease and how to protect our bodies from it"**

Radiation can be damaging to proteins and DNA, causing cancer and potentially affecting the heart. In a paper published in *Frontiers In Cardiovascular Medicine*, Hjortnaes and his team reviewed the evidence of how radiation affects cardiovascular health, and what can be done to protect astronauts. The team looked at evidence from people who had received radiation therapy for cancer, as well as mouse studies of radiation exposure.

They found that radiation could lead to myocardial remodelling: healthy heart tissue is replaced by tough, fibrous tissue, potentially leading to heart failure. Exposure can also cause the build-up of fats and cholesterol in blood vessels, which can cause strokes or heart attacks.

The researchers went on to look at the evidence surrounding protective measures, including radio-protective drugs and changes in diet. They found that an antioxidant-rich diet, including plenty of green vegetables such as spinach, as well as beetroot and tomatoes, was "promising" in reducing the harmful effects of radiation.

However, there is little conclusive evidence, so more research is needed.

"We need to develop human-based tissue platforms, such as heart-on-a-chip systems, that can simulate real human disease, outside of the human body, to unravel the mechanisms at play in space radiation-induced cardiovascular disease," said Hjortnaes.

SPACE

Destination: Mars

Every 26 months, Mars reaches the closest point to Earth in its orbit of the Sun, creating an ideal launch window for spacecraft to make the seven-month journey between the planets. The most recent window opened on 17 July 2020, with three missions arriving on the Red Planet last month. Here's what they hope to tell us about our cosmic neighbour…

PERSEVERANCE

In the Jezero Crater, a dried-up lake, NASA's Perseverance is making itself at home. Equipped with five science cameras, the rover will search for signs of microbial life that may have existed in shoreline or lakebed sediments billions of years ago. Rock core samples will be collected, and some of these priceless commodities are scheduled to make their way to the UK in around 10 years' time.

An oxygen source will be critical for future crewed missions to Mars, which is where Perseverance's onboard oxygen generator comes in. Equivalent to running a fuel cell in reverse, MOXIE will demonstrate technology that splits atmospheric carbon dioxide molecules into oxygen and carbon. But for now, it's the helicopter Ingenuity that's making the headlines. Scientists are preparing it for the first-ever powered flight on another planet, having survived the journey strapped to Perseverance's belly. If successful, this historic achievement could pave the way for future missions to places like Titan, a world many believe to be analogous to early Earth.

Agency: NASA and JPL
Landing site: Jezero Crater
Mission length: One Martian year (687 Earth days)
Instruments:
Mastcam-Z Camera system Studies surface minerals
MEDA Measures wind, temperature, pressure, humidity and dust
MOXIE Demonstrates how to produce oxygen on Mars
PIXL X-ray spectrometer Identifies chemical elements, and has a camera for close-up images
RIMFAX GPR Used to map subsurface geology
SHERLOC Searches for organics, minerals and potential signs of life
SuperCam Camera Examines material, and has lasers and spectrometers to look for organic compounds
Ingenuity Mars Helicopter technology demonstration
Weight: 1,025kg
Size: 2.9x2.7x2.2m
Cost: $2.7bn

Timeline

19 JUL 2020 Hope launches from Tanegashima Space Center, Japan

23 JUL 2020 Tianwen-1 launches from Wenchang Space Launch Center, China

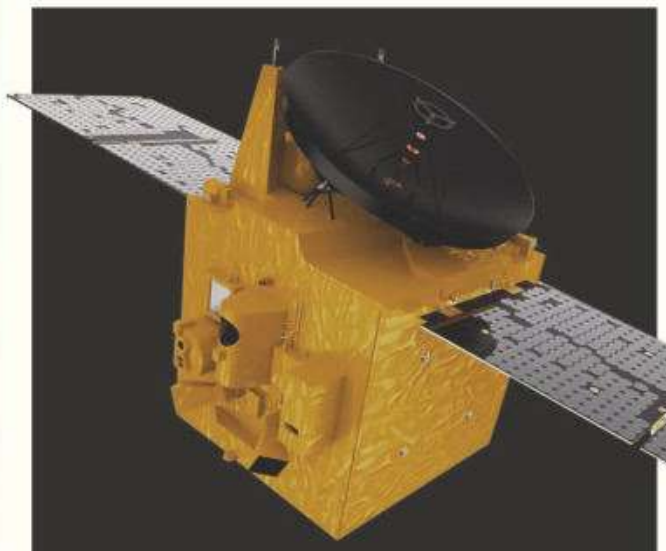
30 JUL 2020 Perseverance launches from Cape Canaveral, Florida

5 FEB 2021 Tianwen-1's first image of Mars, 2,180,000km from the surface

9 FEB 2021 Hope enters orbit

10 FEB 2021 Tianwen-1 enters orbit; Hope sends back its first image of Mars

18 FEB 2021 Perseverance lands, sending back its first image

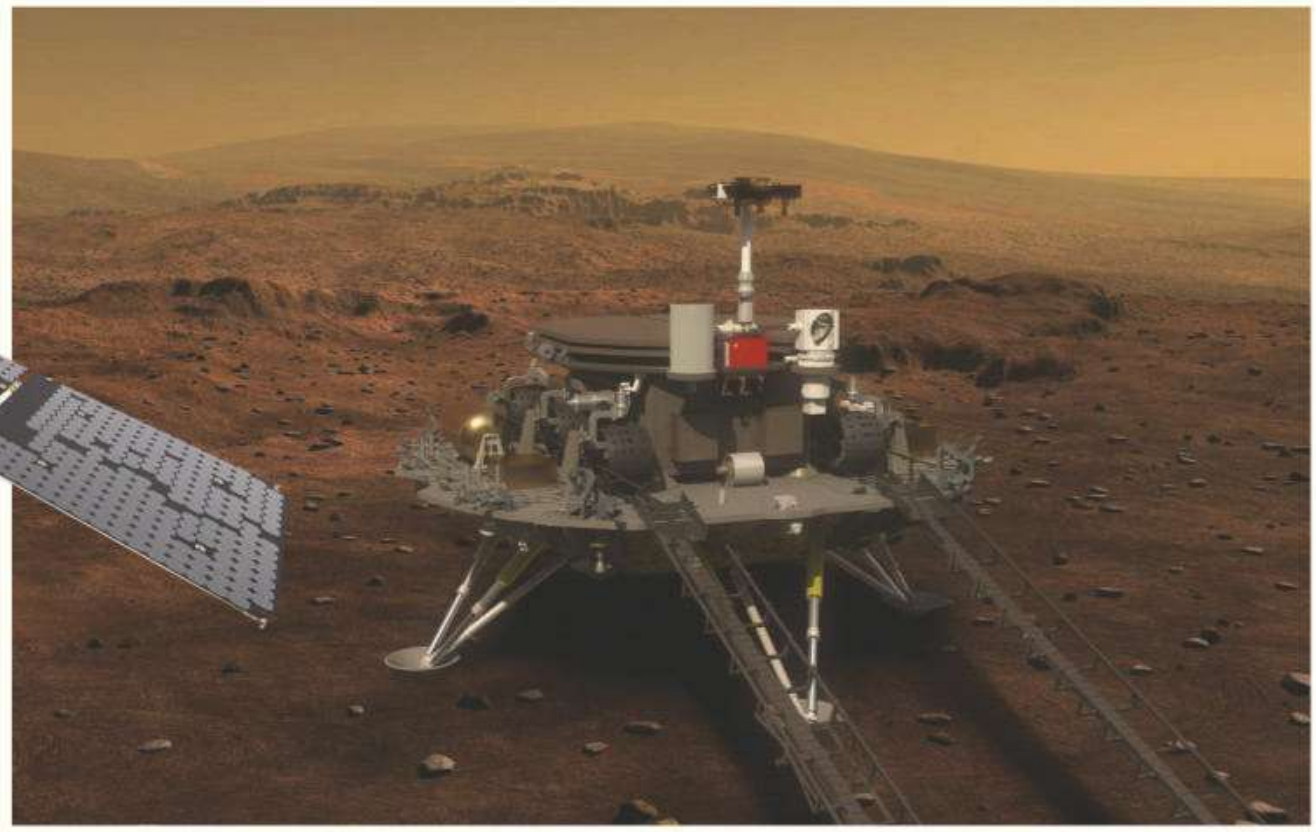


HOPE

The first-ever interplanetary mission by the United Arab Emirates (UAE) is currently in a highly elliptical orbit before beginning a transition phase. It will reach its Science Orbit in May. Hope aims to provide the first complete picture of the thin Martian atmosphere and seasonal variability, as well as addressing lingering questions surrounding hydrogen and oxygen escape.

Agency: United Arab Emirates Space Agency (UAESA)
Target: 22,000km-by-43,000km orbit, which takes 55 hours to complete
Mission length: One Martian year (687 Earth days)
Instruments:
EXI Takes high-res photographs
EMIRS Examines temperature profile, ice, water vapour and dust in the lower and middle atmosphere
EMUS Studies upper atmosphere, as well as hydrogen and oxygen escape
Launch mass: 1,350kg
Size: 2.37x2.90m (3x7.9m open)
Cost: $200m

NASA/JPL X2, ALAMY



TIANWEN-1

Entering orbit less than 24 hours after Hope, China National Space Administration's Tianwen-1 is on a reconnaissance mission before a lander-rover duo attempts touchdown in May. The solar-powered rover will examine surface and subsurface geology, and will look for biosignatures indicative of past life. In potentially the first-ever Martian sample return mission, China aims to transport pristine geological samples back to Earth.

Agency: China National Space Administration (CNSA)
Rover landing site: Utopia Planitia
Mission length: One Martian year (orbiter) 90 Martian days (rover)
Orbiter instruments:
Medium and high-res cameras Study topography, morphology and geology
Magnetometer Studies interaction between ionosphere, magnetosheath and solar wind
Subsurface radar Detects subsurface structures and underground water-ice distribution
Mineralogy spectrometer Determines mineral composition and distribution
Mars ion and neutral particle analyser Studies atmosphere escape and investigates solar wind interaction
Energetic particle analyser Analyses charged particles in the atmosphere

Rover instruments:
Ground-penetrating radar Images below the surface
Magnetic field detector Detects magnetic field
Climate station Measures temperature, air pressure and wind
Surface compound detector Looks for evidence of life
Multispectrum camera Determines material composition and distribution
Navigation and topography camera Provides 360° views for navigation
Launch mass: 5 tons
Size: 2.6x3x1.85m (rover)
Cost: Unknown

22 FEB 2021
Perseverance sends back first-ever audio from Mars

APR 2021
Hope moves into Science Orbit; Ingenuity conducts first test flight

MAY 2021
Tianwen-1 orbiter dispatches lander and rover to Utopia Planitia

29 DEC 2022
Tianwen-1's primary mission ends

6 JAN 2023
Perseverance begins extended mission

13 MAR 2023
Hope begins extended mission

2030
Potential date for Tianwen-1 samples to be returned to Earth

2031
Potential date for Perseverance samples to be returned to Earth

FERTILITY

The most successful sperm poison their competitors

A study in mice has found a genetic variant that gives sperm a 99 per cent success rate – and could explain infertility in human men

What makes some mice sperm so much more successful than others? Probably not a question you've asked before, but it's one that's been answered by researchers at the Max Planck Institute for Molecular Genetics (MPIMG) in Berlin.

When a male mouse carries a genetic variant called 't-haplotype', it has a 99 per cent chance of passing it onto its offspring. The researchers found that the sperm carrying this variant give themselves an edge by poisoning their competitors.

If this trait is also found in human men, the researchers say, this could explain some cases of infertility.

In humans, DNA is encoded in 46 chromosomes. Almost all human cells have all 46 chromosomes, except sperm and egg cells, which contain only 23. When a stem cell divides to form two sperm cells, each sperm cell gets half of the genetic material. This combines with 23 chromosomes in an egg cell to form an embryo with a full set of 46 chromosomes.

In mice with one copy of the t-haplotype gene variant, this means that half of the sperm receive the variant, and half of them don't. The sperm with the variant are so successful that they fertilise the egg up to 99 per cent of the time. The researchers have discovered that the source of this competitiveness all comes down to a protein called RAC1. RAC1 is a 'molecular switch', which tells cells to react to external stimuli. In particular, it controls how the cell moves; it may even help sperm cells to sniff out an egg cell.

Sperm find their way around best when there is an optimal amount of RAC1. "The competitiveness of individual sperm seems to depend on an optimal level of active RAC1; both reduced or excessive RAC1 activity interferes with effective forward movement," said Dr Alexandra Amaral of MPIMG, first author of the study.

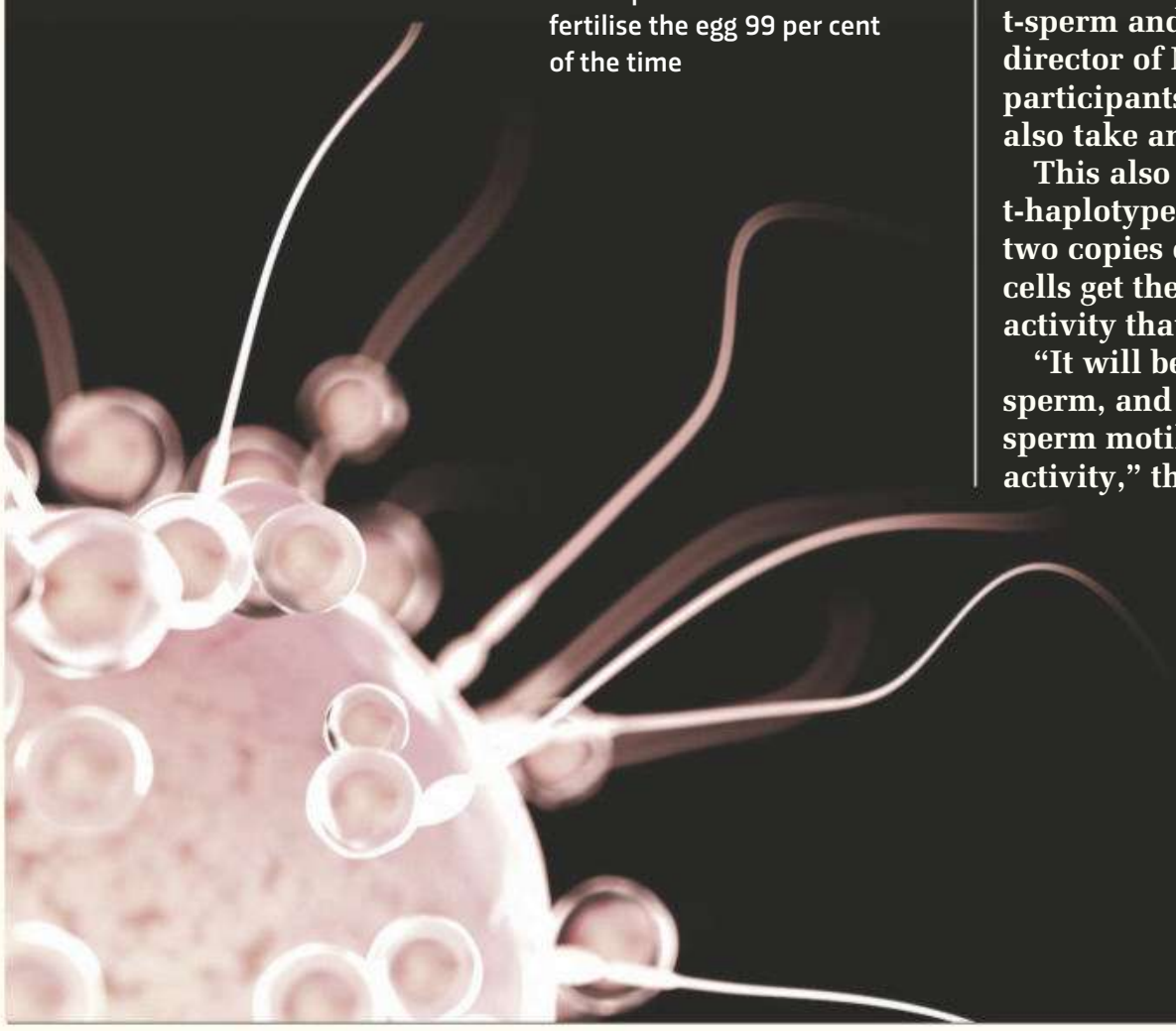
That is, sperm cells depend on RAC1 to be able to move in a straight line. With too much or too little, sperm tend to wiggle around with no particular direction.

The t-haplotype sperm have much higher RAC1 activity than sperm without it. As a result, in mice with the t-haplotype gene variant, there are high enough levels of RAC1 to disrupt all sperm from finding their way towards the egg. However, the researchers noticed that the ones with the variant could still find their way.

"The trick is that the t-haplotype 'poisons' all sperm, but at the same time produces an antidote, which acts only in t-sperm and protects them," said Prof Bernhard Herrmann, director of MPIMG. "Imagine a marathon, in which all participants get poisoned drinking water, but some runners also take an antidote."

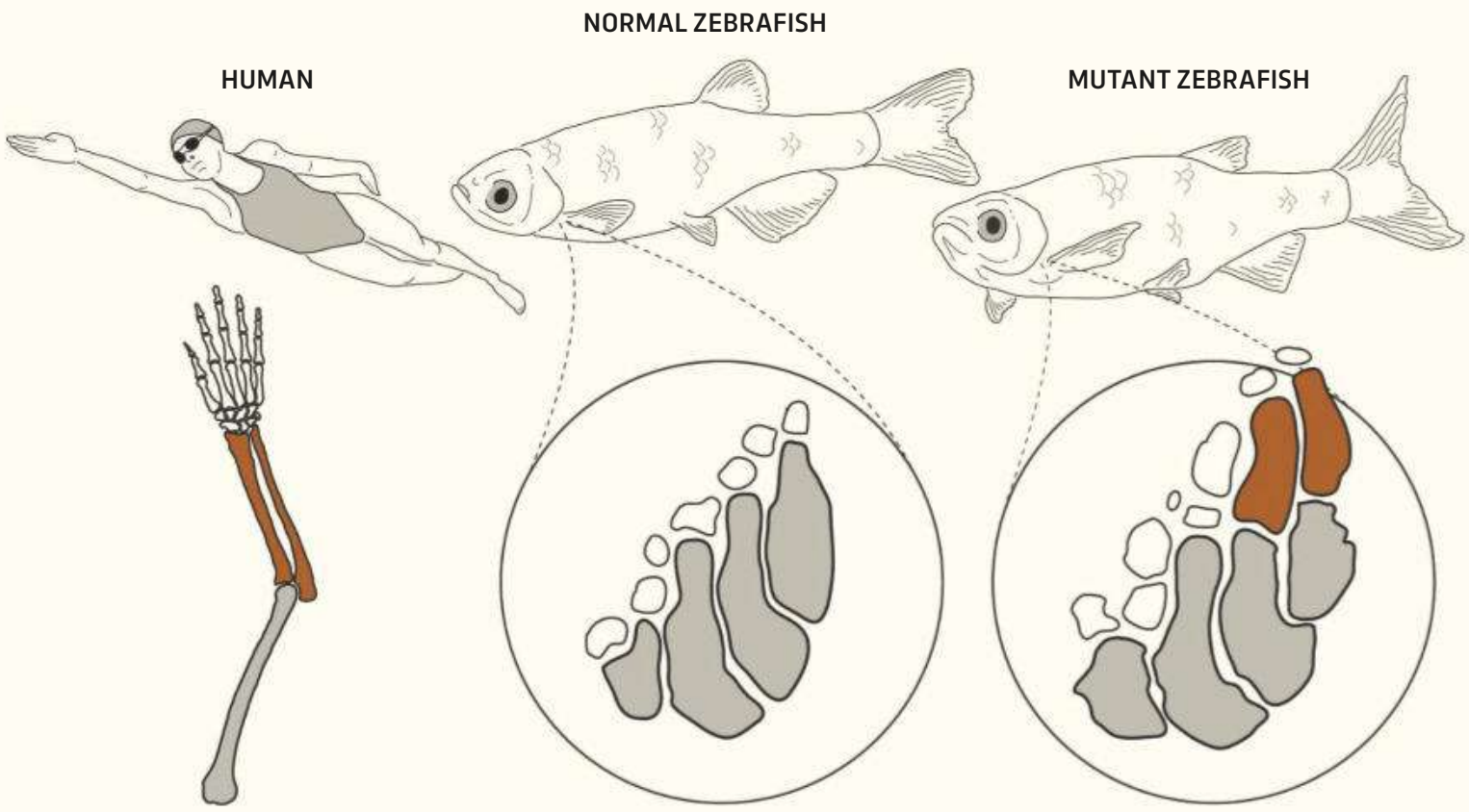
This also means that male mice with two copies of the t-haplotype gene variant, rather than just one, are sterile. With two copies of the variant, when the stem cell splits, all stem cells get the variant. This results in such high levels of RAC1 activity that the sperm cells can barely move at all.

"It will be interesting to see if [RAC1] also controls human sperm, and if any forms of male infertility caused by impaired sperm motility in men may be related to improper [RAC1] activity," the researchers wrote.



The study found that sperm with a particular variant will fertilise the egg 99 per cent of the time

GETTY IMAGES, M BRENT HAWKINS



A small genetic change led to the zebrafish developing extra bones (orange) and joints that are limb-like in pattern

EVOLUTION

Can a fin become a limb?

A single genetic change sheds light on how our ancient relatives first came onto land

The movement of vertebrates from water to land was an iconic step in the evolutionary timeline. Now, research at Harvard University has found that a small genetic change may have been all that was needed to allow a fin to turn into a limb.

The researchers were investigating the mutations that can affect the pectoral fins of zebrafish. Unlike limbs, which have complicated bone structures and numerous joints, zebrafish fins are fairly simple. The team discovered that a small genetic mutation caused the pectoral fins to develop a more limb-like pattern, with extra bones, along with muscles and joints.

"It was a little bit unbelievable that just one mutation was able to create completely new bones and joints," said lead author Dr M Brent Hawkins.

Analysis revealed that mutations in either of two genes, vv2 and waslb, can independently cause this change.

"You didn't need to have a mutation in the muscle gene, a joint gene, and in the bone gene; the system is coordinated such that whatever our change is, it's able to push all these things together in unison," said senior author Dr Matthew Harris, associate professor of genetics at Harvard Medical School.

Zebrafish belong to the teleost group of fish. It's a diverse lineage, with more than 30,000 species, including eels, goldfish, mackerel, clownfish, anglerfish and seahorses. Despite the variety of body shapes, sizes and habitats seen in teleost fish, their pectoral fins are all surprisingly similar and unchanged. This research suggests that fish who were previously thought to have lost the mechanism to evolve limbs, may actually retain a dormant ability to form them.

The development of limbs in tetrapods (four-limbed animals, including amphibians, reptiles, dinosaurs, birds and mammals) was an essential part of evolution, as it allowed vertebrates to emerge from the water and start walking on land. The fin-to-limb transition led to the ancestral fin becoming more elaborate, and evolving many bones that fit together end-to-end. From the same ancestral starting point, the teleost fin became simpler; there are no bones fitting together end to end, instead there are 'proximal radial' bones, arranged side-by-side at the base of the pectoral fins.

The scientists were not able to establish whether the new bones would impact on the locomotion of the fish, but that will be the next step in the research. "Normally, the structures are not present to allow for the articulation required for movement on land," said Harris. "It'd be very interesting to see, for example, if we put our mutant on a platform, whether they would have an adjusted gait."

In numbers

560 billion tons

The amount of organic carbon locked up in submarine permafrost in the Arctic, according to a massive international survey. Human activity has released about 500 billion tons since the Industrial Revolution.

100 million

The number of plants and animals trafficked globally each year to sell as pets, traditional medicines and 'luxury' foods, as estimated by researchers at the University of Sheffield.

FIVE YEARS

The amount by which hearing aids can delay the onset in dementia in people with hearing loss, according to a study carried out at Ulster University in Northern Ireland.

PROF AVI LOEB
Theoretical physicist

Horizons

Could 'Oumuamua be our first recorded brush with alien technology?

In 2017, the Pan-STARRS telescope in Hawaii spotted an interstellar object, 'Oumuamua, passing by Earth for the first time. Since then, Prof Avi Loeb has been investigating its origins

'Oumuamua is often depicted as cigar-shaped, as visualised here. But Avi Loeb says its light signature suggests it is pancake-shaped

GETTY IMAGES

HOW DO WE KNOW THAT 'OUMUAMUA WASN'T JUST A REGULAR COMET?

Most of the objects from the periphery of the Solar System have ice on their surface. The ice warms up when the sunlight hits them, and they end up surrounded with vapour and shrouded with dust. So, we end up with this cometary tail surrounding these icy rocks.

The first suggestion was that 'Oumuamua must be a comet. The only problem was that it didn't look like a comet. It didn't have a cometary tail. There was no gas surrounding it. And in fact, the Spitzer Space Telescope looked very sensitively around it and couldn't find any carbon-based molecules or dust. So it's not a comet.

WHAT OTHER THEORIES HAVE BEEN PROPOSED ABOUT ITS ORIGIN?

One was that it may be a hydrogen iceberg, a chunk of frozen hydrogen. So just like a comet, the hydrogen evaporates from it, but hydrogen is transparent so you can't see the cometary tail. That would explain why we don't see a tail on 'Oumuamua. But I wrote a paper about that with my colleague, showing that a hydrogen iceberg would evaporate quickly as a result of absorbing starlight along its journey. And it's not at all clear that it can be produced in molecular clouds in the first place. We demonstrated that as well, so that doesn't seem likely.

There was a suggestion that maybe it's a collection of dust particles held together in a loose configuration, just a very porous material, 100 times less dense than air. My issue with that is when it gets close to the Sun, like 'Oumuamua was, it would be heated by hundreds of degrees. A cloud of dust that is 100 times less dense than air would not have the material strength, in my view, to sustain this heating.

The third possibility suggested was maybe it's elongated because it's shrapnel: it's a piece of debris of something bigger that got disrupted when it passed close to a star. The problem with that scenario is that you end up with shrapnel that is elongated, usually because of the gravitational tidal force. But the object was most likely pancake-shaped, not cigar-shaped. Also, the chance of it coming close to a star is small.

So, I said to myself, "After two years, is that the best that the community could come up with as an alternative to it being artificial?" In my view, it being artificial is more likely, and there is no clear evidence that it's not artificial.

> **"I don't understand why, even if you're conservative, that you say it's never aliens. Why have a prejudice to start with?"**

SO, WHAT IS IT?

The object was tumbling every eight hours, and showed variations in its brightness by a factor of 10 or more. Since we were looking at the reflected sunlight from the object, this implies that the area it occupied in the sky varied by a factor of 10 as it was tumbling. Think about a piece of paper that is razor thin. The chance of you seeing it edge on is very small. The factor of change is quite extreme and it means that the object was at least 10 times longer than it was wide. And that's what led to this cartoon version of the object looking like a cigar, even though we didn't really have an image of it because it was too small for our telescopes to resolve.

But actually, the best fit to the variation in the light was a pancake-shaped object. So, it was a flat object. And then it exhibited an extra push away from the Sun, which could not be due to the evaporation of gas like you have in a rocket. So, the only way to explain it in my mind was that it was due to a reflection of sunlight. But for that to be effective, you needed the object to be very thin, sort of like a sail that you find on a boat where the wind pushes it, except here it's the sunlight pushing it. But nature doesn't make lightsails. They are artificial.

WHAT EXACTLY IS A LIGHTSAIL?

Light is made of particles called photons. You can think of them as billiard balls bouncing around, and when they bounce off a mirror, they just give a little push. The idea of a light sail is to take advantage of that push. So, for example, you could make the sail sufficiently thin, so that the reflection of light gives it enough push to move it forward. Of course, sunlight is not very powerful, but in principle, if you have a powerful laser beam as the light source, you can reach high speeds. In the case of 'Oumuamua, it was not moving that fast. It's quite possible that it was completely dysfunctional because it was tumbling. And what would you expect from a piece of equipment floating in space for billions of years? Think about New Horizons, Voyager 1 and Voyager 2, when they are a billion years old. They will no longer be functional. So, there could be a lot of trash in space that is not working any more.

YOU RECEIVED A BACKLASH FROM THE SCIENTIFIC COMMUNITY FOR SUGGESTING THE OBJECT COULD BE OF ALIEN ORIGIN. WERE YOU SURPRISED AT THE REACTION?

People are opposed to the mere idea of having the option of it being artificial on the table. That, in my mind, is strange. I left a seminar room where there was a talk about 'Oumuamua and a colleague of mine who has worked on rocks in the Solar System for decades said, "'Oumuamua is weird, I wish it never existed." To me, it was appalling. How can scientists say that? Because, you know, when you're faced with anomalies that take you out of your comfort zone, it's actually a good thing because it means that you're learning something new. If you want to stay in your comfort zone, then just don't look, stay ignorant. You can enjoy life. You can eat good food. You can speak with friends. Just ignore all the facts around you. Many people do that, by the way. But as a scientist, you have an obligation to follow the evidence and see where it leads you. If you are denying that privilege, you are not true to your obligation. And that's the problem I have with the scientific community.

WHAT WOULD YOU LIKE TO HAPPEN NEXT?

Let's deploy cameras around the orbit of the Earth, around the Sun. Lots of them, so that when the next interstellar object is spotted, one of the cameras will be close enough to take a close-up photo. When I go to the kitchen and find an ant, I get alarmed because I know that there should be many more ants out there. The same should be true about 'Oumuamua. We found it after a few years of surveying the sky with Pan-STARRS. If we continue to survey for a few more years, we'll find another one. And then there is the Vera Rubin Observatory [currently being built in Chile] that will come into play in less than three years. It will have much greater sensitivity and could find an 'Oumuamua-type object every month. So, we will have a lot of opportunities to check if I'm right or wrong. I don't understand why, even if you're conservative, that you say it's never aliens. Why have a prejudice to start with? Let's just take a photograph. You know, most of the time on the beach we find rocks, but every now and then we see a plastic bottle that tells us there is a civilisation out there.

PROF AVI LOEB

Avi is the Frank B Baird Jr Professor of Science at Harvard University. His book, Extraterrestrial: The First Sign Of Intelligent Life Beyond Earth (£17.99, John Murray), *which outlines his theories about 'Oumuamua, is out now.* ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer.***

PHOTOGRAPHY

Royal Photographic Society's Science Photographer of the Year winners announced

The winners and standout images were chosen from more than 1,000 entries and will be available to view in an online exhibition run as part of the Manchester Science Festival until 2 May 2021. See the full lineup at **rps.org/spoty**

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SIMON BROWN/RPS SPOTY, SUE FLOOD/RPS SPOTY, NORM BARKER ASIS FRPS/RPS SPOTY, ENRICO SACCHETTI/RPS SPOTY, CHRISTIAN LUNIG/RPS SPOTY, RASMUS DEGNBOL/REDUX PICTURES/RPS SPOTY

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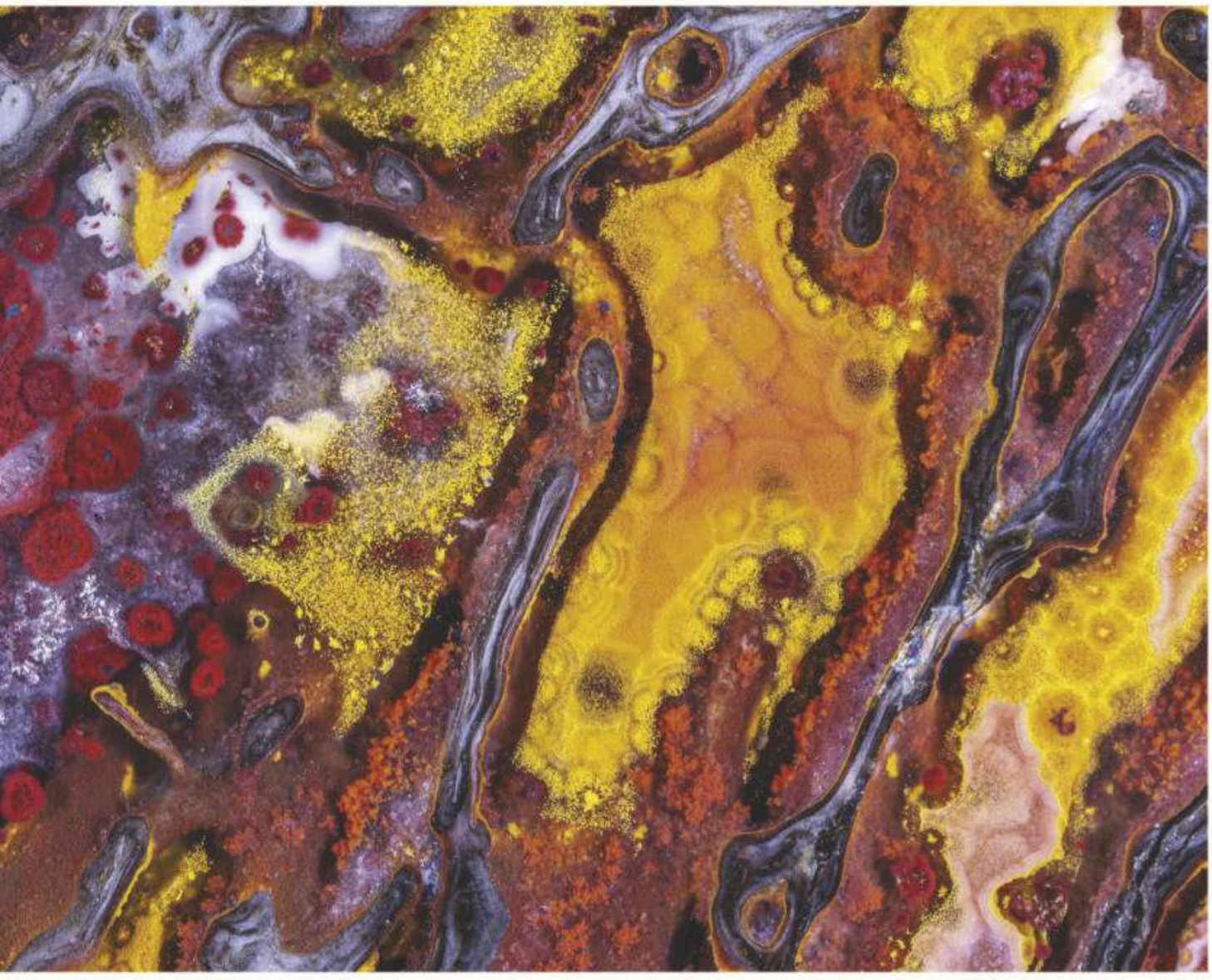

1. Orthophoto of *SS Thistlegorm*
by Simon Brown
This aerial image shows the wreck of *SS Thistlegorm*, a ship that sunk in the Red Sea in 1941. It is made up of 15,005 frames. (Winner – General Science)

2. Giants on the move
by Rasmus Degnbol / REDUX Pictures
A 78-metre long offshore wind turbine blade being transported across a roundabout in Tarp, Denmark. (Shortlisted)

3. Advanced VIRGO+
by Enrico Sacchetti
This picture shows the northern arm of the Advanced VIRGO+ Gravitational Wave Observatory in Tuscany, Italy. (Shortlisted)

4. North Pole underwater
by Sue Flood
A signpost depicting the geographic North Pole at 90° north latitude, placed on sea ice largely covered with water. (Winner – Climate Change)

5. Synlight experiment
by Christian Lünig
Here are some of the 149 xenon arc lamps that form the Synlight experiment in Jülich, Germany. It aims to determine a method of concentrating sunlight to use in the creation of hydrogen fuel. (Shortlisted)

6. Dinosaur bone
by Norm Barker
This is a polished slice through a fossilised dinosaur bone. The colours are due to the changes in mineral content as the fossil formed. (Shortlisted)

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Coronavirus variants | Rat plagues | Obesity treatment

REVIEW

CORONAVIRUS: CAN WE STOP THE SPREAD OF MORE VARIANTS?

From South Africa to Brazil, Bristol and Liverpool, a string of worrying coronavirus strains has emerged. But why? And can we prevent more from developing?

"Because of the constant mutations that occur as the virus replicates, there are likely thousands or even millions of variants of SARS-CoV-2"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

WHAT CAUSES A CORONAVIRUS VARIANT?

During every coronavirus infection, the SARS-CoV-2 virus makes many new copies of itself. For each new copy, the virus has to duplicate its genome. And during this duplication, small errors can occur, so that each new copy of the genome is slightly different from the last.

In short, these errors are the mutations that create a coronavirus variant. These mutations happen all the time, creating more and more variants, but most have no effect on how the virus behaves. Occasionally though, a mutation will cause a change in some aspect of how the virus behaves. These are the "variants of concern" that we have been hearing about.

WHY ARE SO MANY VARIANTS EMERGING NOW?

Because of the constant mutations that occur as the virus replicates, there are likely thousands or even millions of variants of SARS-CoV-2.

The more times the virus replicates (and the greater the number of people infected), the more mutations will occur and the more variants we will have. With over 112 million cases of COVID-19 worldwide, it is normal and expected for there to be this many variants.

However, headlines seem to be filled with news of new variants of concern. The reason for this is not that we're suddenly getting more virus mutations or variants, but that the virus likely now has more selective pressure for variants that help it in some way.

What does this mean? Well, earlier in the pandemic, the majority of the world did not have any protective immunity against the virus. But now more and more people have either been infected or vaccinated, giving protection from further infection. Because of this, any virus with a mutation that doesn't produce an immune response will likely spread better (as we are seeing in the South African B.1.351 variant).

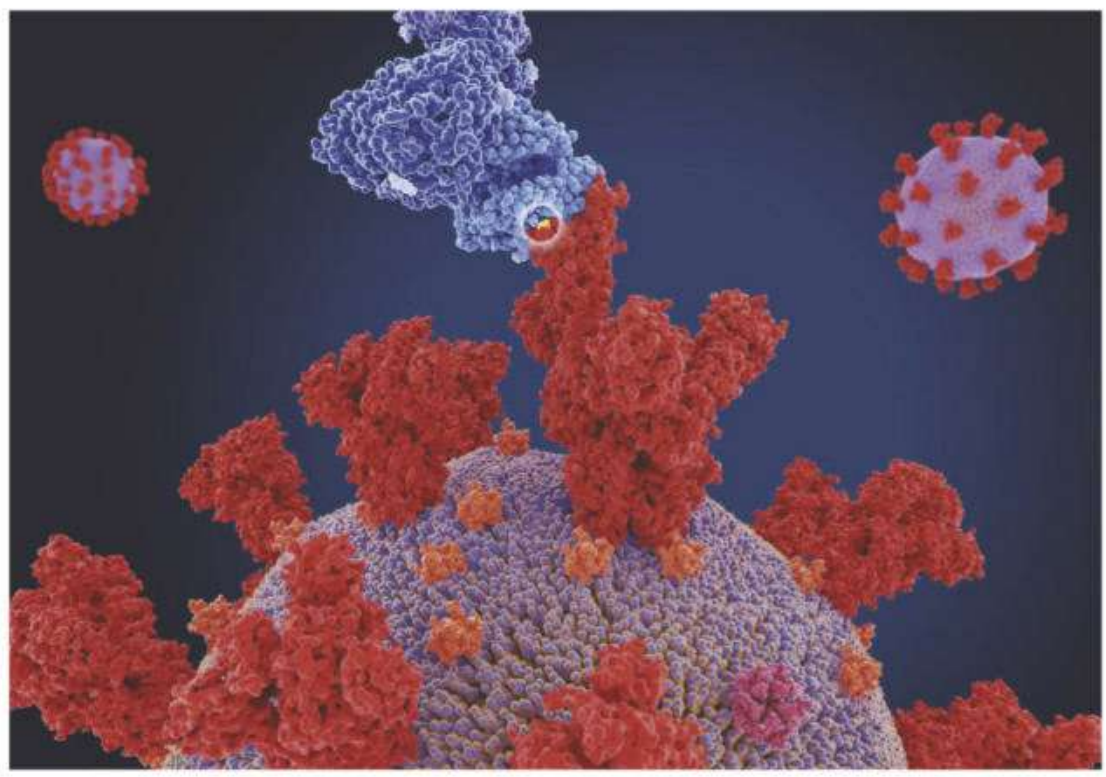
SHOULD WE BE WORRIED ABOUT ANY NEW VARIANTS?

As long as the virus continues to spread, we will have new variants. Most of these variants will not affect the pandemic at all. However, there are two areas of concern.

First, it is possible that a new variant will emerge (by chance) with an altered behaviour that happens to make the virus more transmissible or deadlier. This is not an inevitability. It is just as likely that the virus would mutate to cause more mild disease.

The second and larger concern is that the virus will mutate and evade an immune response. This means the virus could either re-infect people or infect people that have been vaccinated. We are currently seeing this change with the South African B.1.351 variant and the Brazilian P.1 variant.

Immune-evading mutations are beneficial for the virus as they allow the virus to infect more people. Thus, as more and more people build protective immune responses (either after recovering from infection or by vaccination), the pressure on the virus increases and the likelihood of immune-evading variants increases. For comparison, the influenza virus changes enough every year that we need a ➲



GETTY IMAGES, SCIENCE PHOTO LIBRARY

BELOW Illustration of the spike protein (red) from the B.1.531 coronavirus variant binding to a host cell (blue). The mutation site is coloured yellow

new vaccine. SARS-CoV-2 doesn't mutate as rapidly as the flu, but there is a concern that the continual emergence of new coronavirus variants will necessitate new booster vaccines at regular intervals.

ARE WE DOING ANYTHING TO ENCOURAGE MORE VARIANTS?

Unfortunately, the actions of many countries are encouraging more variants. By not effectively stopping the spread of the virus, we are giving the virus more chances to mutate. And the more COVID-19 infections, the greater the chances of a new variant emerging with changed behaviour.

It is possible that this generation of new variants could be enhanced by delaying the time between the first and second vaccine dose in the UK. The rationale for delaying the second vaccine dose is to enable as many people as possible to get some level of vaccine-induced protection as quickly as possible. This seems like a good strategy for a limited supply of vaccine.

However, we know that after one vaccine dose it's still possible to be infected by the virus. And there is a chance that these infections could drive the evolution of the virus toward variants that evade the immune system.

There is no evidence that this is currently happening. But just as a partial course of antibiotics could lead to antibiotic-resistant bacteria, it is possible that a partial course of vaccine jabs could lead to immune-evading SARS-CoV-2.

CAN WE DO ANYTHING TO STOP VARIANTS EMERGING?

The single best thing we can do to stop new variants emerging is to reduce the number of coronavirus infections worldwide. This is because each new infection has a chance of creating a new variant that behaves differently.

We all want to rely on vaccines as a quick way out of the pandemic. But, on their own, vaccines will likely result in new variants that evade immunity – which is possible in a matter of months). As scientists argue, we need to continue to support our vaccines with strong public health measures.

by **DR JEREMY ROSSMAN**

Jeremy is senior lecturer in virology at the University of Kent.

ANALYSIS

RATS: ARE WE REALLY SEEING PLAGUES OF RODENTS IN OUR CITIES DURING THE PANDEMIC?

As if COVID-19 wasn't stressful enough, some outlets have claimed that rodents are now taking over our empty offices and cities. But is this really the case?

Rats are on the move. While there have been restrictions on humans during lockdown, the same cannot be said for rats. There is increasing evidence that the COVID-19 pandemic has resulted in a radical shake-up of rodent society.

ALAMY

ABOVE Rats generally have a small home range of around 30 metres in diameter

Within weeks of the first lockdown in March 2020, around 50 per cent of pest controllers across the UK were reporting increased signs of rat activity when out on a job, according to a survey conducted by the British Pest Control Association (BPCA). By October, the situation had got even worse, with almost 80 per cent of BPCA members observing an increase in rat activity.

Why would this be? "Rats benefit and thrive from the things that we do," says Natalie Bungay, the BPCA's technical and compliance officer. Rubbish sacks stacked on the pavement or half-eaten takeaways tossed into a bin are a handout for rats. "They need about 200g of food a day and as long as they can find that they'll be fine," she adds. But with fewer humans on the streets, restaurants shuttered and less free food waste, many rats are having to graft harder to make ends meet. This means straying beyond the confines of their covert, largely nocturnal existence, resulting in rats turning up in places and at times of the day when they would not normally be seen.

Brown and black rats are the two most common city-dwelling rat species in the world. Brown rats are much more common in temperate regions like the UK, as they are more resistant to cooler climates. Both rat species have a pretty small home range of around 30 metres in diameter. Even then, they will normally stick within an even tighter comfort zone, an area that can be just 10 per cent of their overall territory. "Because we're not there [in the cities], the rats haven't got their food source and are having to extend their feeding range," says Bungay. In addition, the cold weather of recent months is likely to have driven rats indoors. "We always get more calls for rodent infestations in winter," she says. With many offices either empty or operating with a skeleton staff, there is no shortage of spaces for rats to explore with relative safety.

> "Even those of us who study rats full-time can make few educated guesses about how many there are"

All of this makes biological sense, but without systematic monitoring of these mammals, there's very little data to indicate whether there has actually been any change in the rat population. We just don't know, admits Bungay. "It's all based on opinion and assumption," she says.

HIDE AND SQUEAK

"Wild rat research isn't sexy," says Dr Michael Parsons, an urban ecologist at Fordham University in New York. "It isn't well-funded and even those of us who study rats full-time can make few educated guesses about how many there are." What he can show, however, is that when Manhattan went into lockdown in March 2020, the number of rat sightings logged on the city's NYC 311 reporting system actually went *down* by some 30 per cent compared to a normal year.

"Most researchers I have spoken with believe there was an initial decrease in rat numbers because rats were stressed by the closing of restaurants," says Parsons. This may have resulted in natural selection, with the bolder, more resourceful, risk-taking rats more likely to survive to pass on these characteristics to their ➲

Rats may have become bolder during the COVID-19 pandemic, as they have to travel further afield for food

offspring, he suggests. "Once restaurants re-opened, rats had access to their old feeding grounds as well as the new areas that a few desperate, risk-taking rats may have found." So even if there really was an initial decrease in the New York rat population, it's likely it has bounced back and may even have increased, says Parsons.

Does any of this matter? For most people, the idea that rats really might be squeezing their way up from the sewers and gnawing their way into our homes is likely to elicit a shudder, but losing a bit of food to a rodent is no biggie in the grand scheme of the pandemic. But the economic cost of rat damage in the US is estimated to be $19bn a year and this doesn't even factor in the very real threat they pose to public health.

The list of diseases that can be carried by rats is long. A study in the 1990s took a close look at 600 wild brown rats captured on farms in southern England and found they were riddled with fleas and mites, and were reservoirs for a cocktail of disease-inducing viruses, bacteria, protozoans and worms. There is no evidence that rats could be vectors of the SARS-CoV-2 virus, but as fragments of the virus's genetic signature has been detected in wastewater and it is known to survive on a range of different surfaces for several days, this is at least a possibility.

If the COVID experience has taught us anything, it's that we need to be careful about how close we get to wild animals. "Rats are so important that more effort should be spent on behavioural and disease surveillance," says Parsons.

—

by **HENRY NICHOLLS**

Henry is a science journalist and editor.

COMMENT

OBESITY: COULD A NEW APPETITE-CONTROLLING DRUG BE THE TREATMENT WE'VE BEEN CRAVING?

In a large trial, people injected with semaglutide lost significant amounts of weight. Could this drug help tackle the obesity epidemic?

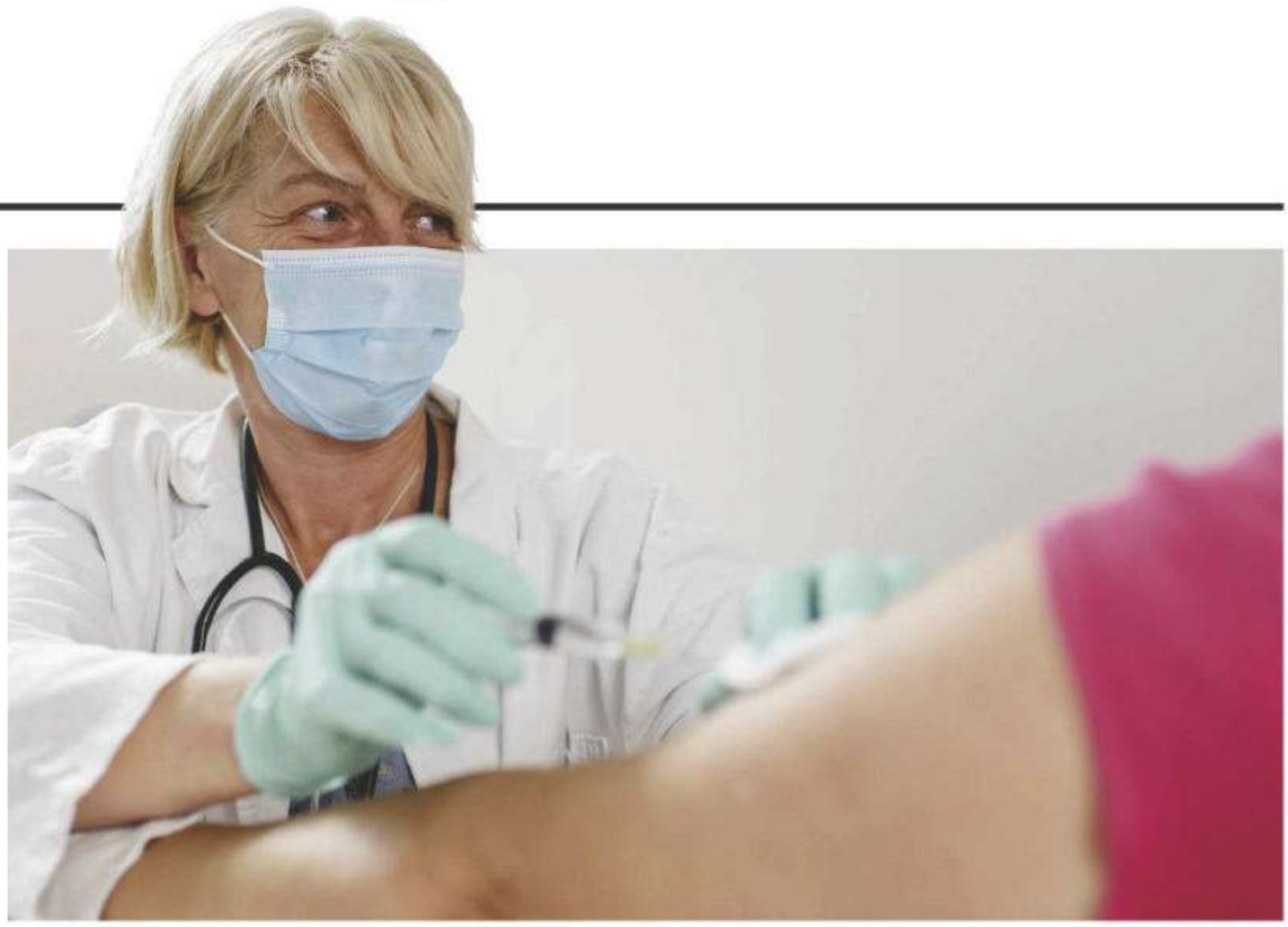
We need effective strategies for the prevention and treatment of obesity as much as for COVID-19. According to NHS data published last May, 26 per cent of men and 29 per cent of women in the UK were estimated to be obese – defined as having body mass index greater than 30. The situation may now have deteriorated owing to lockdown-related weight gain. Not only are obese patients more likely to die from COVID-19, but recent estimates by researchers at the University of Glasgow suggest that obesity may have overtaken smoking as a cause of ill health in England and Scotland.

A healthy balanced diet combined with appropriate levels of physical activity can prevent weight gain, but it is not an effective treatment for obesity. Very low-calorie diets, consuming less than 1,000kcal per day, can result in weight loss of 10 to 15kg in up to 12 weeks. More modest moderate calorie restriction, as used by most commercial slimming plans, can result in an average weight loss of around 7kg a year. However, any weight lost by these methods is usually regained, so another approach is needed.

To date, most drugs developed to treat obesity are either ineffective in clinical practice or have nasty side effects such as increasing blood pressure or causing anal leakage. Bariatric surgery is currently the only effective treatment for severe obesity, but it comes with risks and long-term side effects. One reason why bariatric surgery is so effective is because it changes how the gut responds to food intake and talks to the brain. In the body, a series of peptide hormones are secreted in the intestine that sense food intake and play a role in regulating appetite and energy expenditure. One of these hormones, called glucagon-like peptide (GLP-1), is released in the final section of the small intestine in response to carbohydrate-containing foods. This promotes production of insulin in the pancreas, but also puts a brake on the rate at which food passes from the stomach into the small intestine.

ALAMY, GETTY IMAGES

"The patients in the semaglutide group lost an average of 15.3kg compared with 2.6kg in the control group"



In the brain, GLP-1 receptors play a part in appetite control, with the net result being that you feel less hungry.

A groundbreaking large double-blind trial in otherwise healthy, obese patients without diabetes was recently published in the *New England Journal of Medicine* by UK researchers led by John Wilding. It involved the use of semaglutide, a drug that mimics GLP-1. The drug was originally developed to treat diabetes, but it was also found to cause substantial weight loss in patients with type 2 diabetes.

For this new research, the team recruited 1,961 patients, 75 per cent of whom were female, 75 per cent white, 13 per cent Asian, and 6 per cent black, with an average body mass index of 38, and randomly allocated them into two equal groups. One group received weekly injections of semaglutide, while the other group was given placebo injections for 68 weeks. Both groups also received diet and lifestyle advice.

The patients in the semaglutide group lost an average of 15.3kg compared with 2.6kg in the control group. The treatment also lowered the blood pressure by an average of 5.1mmHg, and patients reported improved physical functioning. The main side effects of treatment were nausea, and sometimes vomiting and diarrhoea. Of concern may be an increased risk of gallbladder disease and pancreatitis.

While this trial shows semaglutide promotes a greater weight loss than any other drug so far tested, what happens when treatment stops is uncertain. Preventing weight regain is a major challenge, and the lesson from bariatric surgery is that patients need to avoid unhealthy snacking and sugary drinks in addition to downsizing portions of high-calorie foods. Confirmation of these research findings is also needed in a more ethnically diverse population with a higher proportion of men. And from a practical standpoint, the requirement for weekly injections of the drug is likely to limit a wider rollout. However, oral preparations of this class of drug have been developed and are undergoing trials.

While semaglutide looks like a promising treatment for severe obesity, it is not a magic bullet. We must continue to promote a healthy lifestyle as well as measures to discourage the adoption unhealthy eating habits that are causing obesity. It is rather like the situation we are in with the COVID-19 and the vaccines – we still need to stick with public health measures and not become overdependent on medicines. **SF**

ABOVE A weekly injection could show promise in reducing obesity

by **PROF TOM SANDERS**

Tom is emeritus professor of nutrition and dietetics at King's College London.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

The new technique could make it easier and safer to extract rare earth metals from used devices

RARE EARTH RECYCLING

MAGNETIC ATTRACTION

Chemists at the University of Pennsylvania have separated rare earth metals for recycling by exploiting their differing levels of attraction to a magnetic field. The method can separate heavier rare earth metals from lighter ones.

CHEMICAL BREAKDOWN

The University of Birmingham is setting up a facility to recycle rare earth metals used for magnets in hard drives, appliances and electric cars. Hydrogen breaks down the alloys into a powder that can be separated from the other components.

OLD BECOMES NEW

The Critical Materials Institute in the US recycles rare earth metals by stripping the coatings off the magnets found in hard disks, before crushing them into powder. The powder is then heated with a plasma torch to form another magnet.

MATERIALS

A cheaper, quicker and cleaner way to recycle more of your gadgets

New method enables rare earth metals to be more easily extracted from batteries, computers and electric cars

Smartphones, tablets, laptops and electric cars may help the environment by being rechargeable, but they're not doing it many favours when it comes to recycling. The batteries, magnets and motors used inside them contain rare earth metals, such as lanthanum, neodymium and dysprosium, which are expensive and time-consuming to separate and process so they can be reused elsewhere. To make matters worse, extricating the metals from the gadgets can produce harmful waste. As a result, rare earth metals are rarely recycled – currently the rate stands at around 5 per cent.

"RARE EARTH METALS ARE RARELY RECYCLED – THE RATE STANDS AT 5 PER CENT"

But in February, a team of material scientists from Iowa State University in the US Department of Energy's Ames Laboratory submitted a patent application for a new method that would make recycling such metals easier, cheaper and cleaner.

To typically recycle such metals, you'd have to crush the parts containing them into a fine powder, then use chemicals to convert and separate the desired elements out of the alloys. It's a method that not only requires high temperatures and a lot of time, but also uses strong acids that lead to dangerous waste.

The new method being proposed involves adding either ammonium salt or iron III salt to the parts being recycled. The parts are then ground down and dropped into water, which can be at room temperature, to begin the process of separation that can take as little as two days.

The team behind the process say it can be used to extract 16 of the 17 rare earth metals, as well as nickel and cobalt, that are found in the batteries and magnets used in electronic devices and vehicles. What's more, the salts used in the new extraction process are abundant, inexpensive and can be recovered and reused afterwards.

An increasing shift towards electric vehicles is necessary if we are going to hit emissions targets in order to combat climate change, which means the demand for rare earth metals is set to grow rapidly over the next decade. Since mining the metals is harmful to the environment, the need for an effective and efficient method of recycling them with as little environmental impact as possible is vital. The method being proposed by the Iowa State University and Ames Laboratory scientists might just be the answer.

Batteries used in electric devices and cars contain valuable rare earth metals

GETTY IMAGES, ALAMY, WIKI COMMONS, ERIC SUCAR/PENN STATE UNIVERSITY

INTERVIEW

The truth is out there

Bellingcat, the investigative journalism site, has broken some of the biggest stories of the decade. Their investigators proved that Bashar al-Assad fired chemical weapons at his own people, they discovered who downed flight MH17 and, most recently, they put Russian opposition leader Alexei Navalny on the phone with one of the men sent to assassinate him. They're not spies, and they're not trained, so how do these laptop-wielding 'amateurs' hold power to account? Bellingcat's founder Eliot Higgins talks to Daniel Bennett about why people need an intelligence agency, how internet investigations work and how we can fight misinformation.

WHAT IS BELLINGCAT?

We're a small, non-profit NGO [non-governmental organisation]. We have about 20 staff members and we carry out online open-source investigation. We use material that's available online – from social media posts to satellite imagery from Google Earth – to investigate different incidents, like war crimes in Syria, Russian poisoning, and wildlife trafficking. The name is from *Belling The Cat*, a fable about a group of mice who are scared of a large cat. They come up with the idea of putting a bell around its neck, but they don't know how to do it. So, we're teaching people how to bell the cat.

HOW DID YOU START OUT?

Before this, I was working in an admin job. I had no specialisation, no affinity for what I did, but I was spending a lot of time on the internet arguing with people about what was happening in the world. And, at the time, in 2010, that was the Arab Spring. People would share videos and debate about whether they were real or not. But no one actually tried to figure out if they were genuine. Then I found a video. It was in a place called Tiji in Libya. The rebels posted a video claiming they had captured this. In it there was a tank rolling down a road with two wide lanes of traffic, a mosque next to the road and various other buildings. So I thought, "maybe I can find this road and mosque". I went to Google Maps and I found the town easily. Then I looked at the satellite map, it clearly had a major road running through the middle. I zoomed in. Two lanes. I followed it and there was a mosque on the road with a dome and a minaret. It matched what was in the video. I started to look at the smaller details: the curve of the road, the appearance of the walls, the utility poles. I could be sure that this was the location they said it was.

I could go back and win the argument about whether this video was legitimate. That's where it started, but I found it fascinating you could do this. I was frustrated that the reporting was so focused on what was happening from the perspective of the journalists on the ground, while there was so much information being shared online from a range of different sources that was being ignored because people felt they couldn't verify their authenticity.

But if you actually examined and analysed the videos, you could get a much more granular view of the conflict. I kept doing this and in early 2012 I started a blog, a place where I could put my thoughts. There were so many people watching these videos and basically creating conspiracies around them. I wanted to write about what I could see, not what my opinions were.

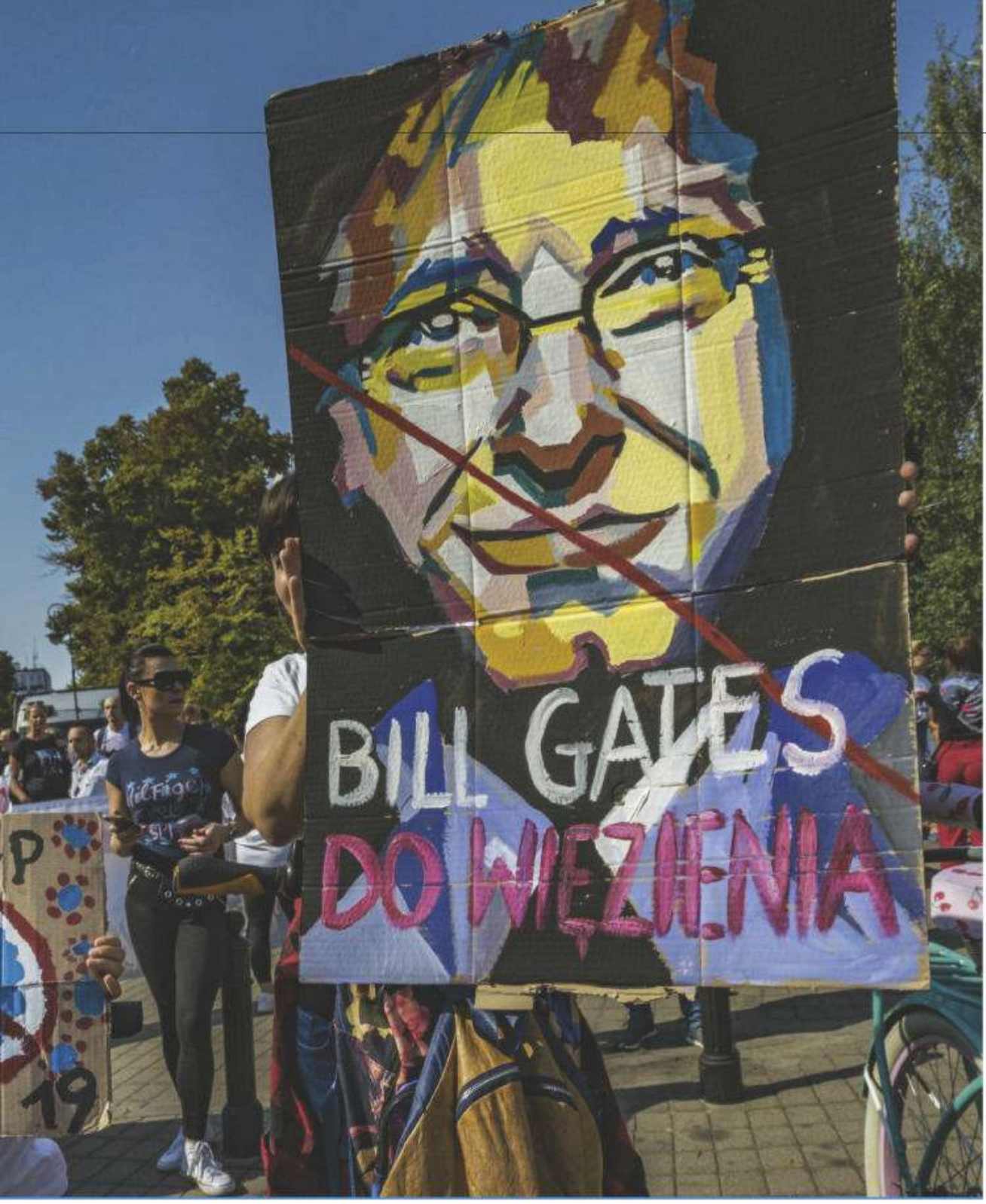
HOW DID YOU GO FROM A BLOG WITH A GROWING FOLLOWING TO THE CREATION OF BELLINGCAT, AN INTELLIGENCE AGENCY?

The company I was working for was making people redundant and I was on the chopping block. I had a company approach me based on my blog, to find out if their workers were in danger of being attacked by Al-Qaeda, that kind of thing. The salary was good, but I would have had to have shut down my blog if accepted. I had a mortgage, so I told people on Twitter I was stopping my blog. But then people suggested I try to get some crowdfunding. I scraped together £12,000 and that allowed me to work on it full time.

WHAT HAVE YOU BEEN ABLE TO UNCOVER SINCE?

Our first big investigation would have been into flight MH17 [the Malaysian Airlines flight that was on its way from Amsterdam to Kuala Lumpur in July 2014 when it disappeared over conflict-torn Ukraine]. This was when our investigation team, which was a group of volunteers, really formed. Most have now become staff.

↓ Eliot Higgins, founder of Bellingcat



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We tracked the missile launcher that was believed to have shot the plane down. We then found the location the missile was fired from in Ukraine. Next, we identified the launcher in a convoy in Russia a few weeks earlier that was headed to the Ukrainian border. Then we started identifying individuals who were on phone calls published by the criminal investigation, the investigation team and the Ukrainian security services. We showed that Russia was involved in what took down the flight.

Other big stories have included proving the use of chemical weapons in Syria. We also identified the people involved in the Skripal assassination attempt. That investigation led us to Russia's nerve agent programme, which eventually led us to the team who tried to assassinate Alexei Navalny, the opposition leader in Russia. We've also looked into the wildlife trade in Dubai, and the emergence of the extreme far right in Europe, the US and more.

WHO ARE THE PEOPLE BEHIND BELLINGCAT?

We're kind of wacky amateurs who have hobbies that get out of hand. Take the Russian investigations: all these discoveries are basically the work of one person who just focuses on this kind of evidence and working in that particular way. Although we have 20 people on our staff, there might be one or two people working on each investigation.

We're also part of a broader community of experts, journalists and people working in NGOs. There are military, arms and chemical weapons experts too. Then there are members of the public who we connect to through social media. Because it's all using open-source information, anyone can join in and look at our investigation. Anyone can be a part of it. It's a clear and transparent process.

DO YOU WORRY YOU'RE ANNOYING SOME QUITE POWERFUL PEOPLE?

I have to be more cautious now. When I'm travelling I don't eat food in hotels. I won't have room service because I just don't know where it's from. Once I was staying at a hotel that I'd visited for quite a few years. There was a knock at the door, late at night. I opened the door and there was a man in a suit with a name badge. He'd said he'd brought me free cookies for staying 10 times at the hotel. I took them, thinking "great, free cookies". But then I realised I had no idea who that person was. You can get a name badge anywhere. I started getting suspicious. In the end, I put the cookies and sweets in the bin. Then, when I left, another staff member came over and said "we hope you enjoyed the cookies", just after I'd checked out. I'd thrown those cookies away for nothing.

RIGHT NOW WE'RE SEEING THE RISE OF DISINFORMATION FUEL A TIDAL WAVE OF NEW CONSPIRACY THEORIES. IS BELLINGCAT AN ANTIDOTE TO THAT?

In a sense, yes. There's a fundamental distrust in traditional sources of authority. Lots of people distrust the media, the government, medical professionals and so on. If you feel that way, you'll go online, and you'll look for an alternative. You'll find people who'll tell you that the Earth's flat, that QAnon is real or that coronavirus is being caused by Bill Gates. They'll tell you that your suspicions are right and that everyone outside their community is being deceived. They start building this almost heroic sense of themselves: that they're the ones who know the truth and that everyone outside it is a poor, misguided fool. These bubbles start to become detached from reality and it's hard to reach them.

So I think what we have to do as a society is look at how we can actually engage people who are looking for alternative sources of authority and show them how to develop their own authority through evidence-based investigation. This is why we spend a lot of time training people who are school or university age to do investigations. Show them that they're not powerless. If I can sit at a laptop and expose Russian spies left, right and centre, anyone can. There's nothing special about what I've done. It belongs to all of us.

↖ Bellingcat can help provide an antidote to conspiracy theories

ELIOT HIGGINS
Eliot is the author of We Are Bellingcat: An Intelligence Agency For The People *(£20, Bloomsbury).*

Ideas we like...

→

A sustainable waterproof shell

Conventionally speaking, waterproof coats are sprayed with a water-repellent chemical that makes rain bead up and roll off the coat, instead of soaking in. The coating also means the material beneath it can be breathable, stopping from you getting too hot underneath. Unfortunately, those chemicals have a habit of washing off, shortening the coat's life and polluting the environment. Now, Helly Hansen is using a new kind of material that has small enough pores to keep water from coming in, but lets hot vapour (sweat) out. This potentially means the coat could stay waterproof for its entire life, with no need for extra coatings, or the pollution that comes with the process.

Helly Hansen Odin Minimalist Infinity Shell jacket
£600, hellyhansen.com

←

Backpacks that give back

The brand behind this roll-top bag is called Bear and its founders have a mission: to get more people outside to talk about their mental health. Sales from each bag will be funding free outdoor workshops, from fly fishing to foraging to off-road cycling. Shoppers just have to sign up to their mailing list to find out when courses start. In the meantime, while we're all stuck mostly indoors, Bear will donate 10 per cent of sales to The Outward Bound Trust. On top of that the company is carbon negative, relying on recyclable, fossil-fuel-free materials where possible and carbon-offsetting the rest. The actual bags are pretty smart too. There's a quick release buckle holding the top together, which is same one used by the rescue services, and the waxed canvas is made in Scotland without the use of PFCs (the chemicals typically used in waterproof coatings), which can run off into the environment.

Gouthwaite 25L backpack
£165, bearmade.co.uk

↓

An affordable, discreet gaming headset

The new official gaming headset for the Xbox Series X and S packs in a lot of features without costing a small fortune, and for once, it won't make you look like an extra in a *Tron* film. The cans are kitted out with the latest surround sound (Windows Sonic, Dolby Atmos and DTS) so that you can really hear those footsteps creeping up behind you. There's a smart, retractable microphone inside that can isolate your speech and tone down background noise. Plus, it offers an auto-mute option, which turns off the mic when you're done speaking: no more accidental heavy breathing over comms. We'll have to reserve full judgment until we can get a pair on our ears, but it looks like this could be the smart way to get immersive sound on your new Xbox.

Xbox wireless headset
£89.99, xbox.com

An exercise bike that minimises the time you spend on it

"Get fit and healthy in 26 minutes a week." That's the bold claim made by the creators of this exercise bike, which combines high-intensity training with an algorithm that learns your fitness level and creates a training regime. The bike is built on the idea that energetic bursts of exercise are effective at making you healthier. Research that we've reported on in previous issues of *BBC Science Focus* seems to support this idea, with several studies showing that periods of high-energy activity interspersed with more sedate intervals seem to push your body out of its comfort zone, improving heart health, lung capacity, fat-burning potential and more. If you're serious about training, the bike plugs into the growing market of online classes, including Peloton Digital and Apple Fitness+.

Carol exercise bike
£2,995, carolfitai.com

A cinema camera almost the size of a compact camera

Sony's FX3 is the smallest and cheapest cinema camera the company has ever made. It's built for filmmakers rather than photographers, so it can handle recording Ultra HD video at 120fps for long periods. It comes bundled with a handle that's ideal for shooting from low angles, and it adds extra sockets for plugging in different audio inputs. There's also in-body image stabilisation for when you're 'running and gunning'. The camera will also play nice with Sony's yet-to-be-released Airpeak drone. At 715g, the camera is a bit too bulky to fit in your pocket, but it's light and small enough to take wherever you go. Keep an eye out for it in the hands of your favourite YouTuber soon.

Sony FX3
£4,200 approx, sony.co.uk

A cycling helmet light that recharges itself

Sat beneath the surface of this helmet is a light-harvesting material called Powerfoyle, which converts solar energy into electricity. After cycling to work in the morning, leave the helmet by a sunny window to charge and by evening you should have a fully juiced red light on the back. Bung the helmet on and the sensors inside turn on the light. The light isn't bright enough to warrant binning those bike lights you keep forgetting to charge, but it will improve your visibility to others.

POC Omne Eternal
€250 (£216 approx), pocsports.com

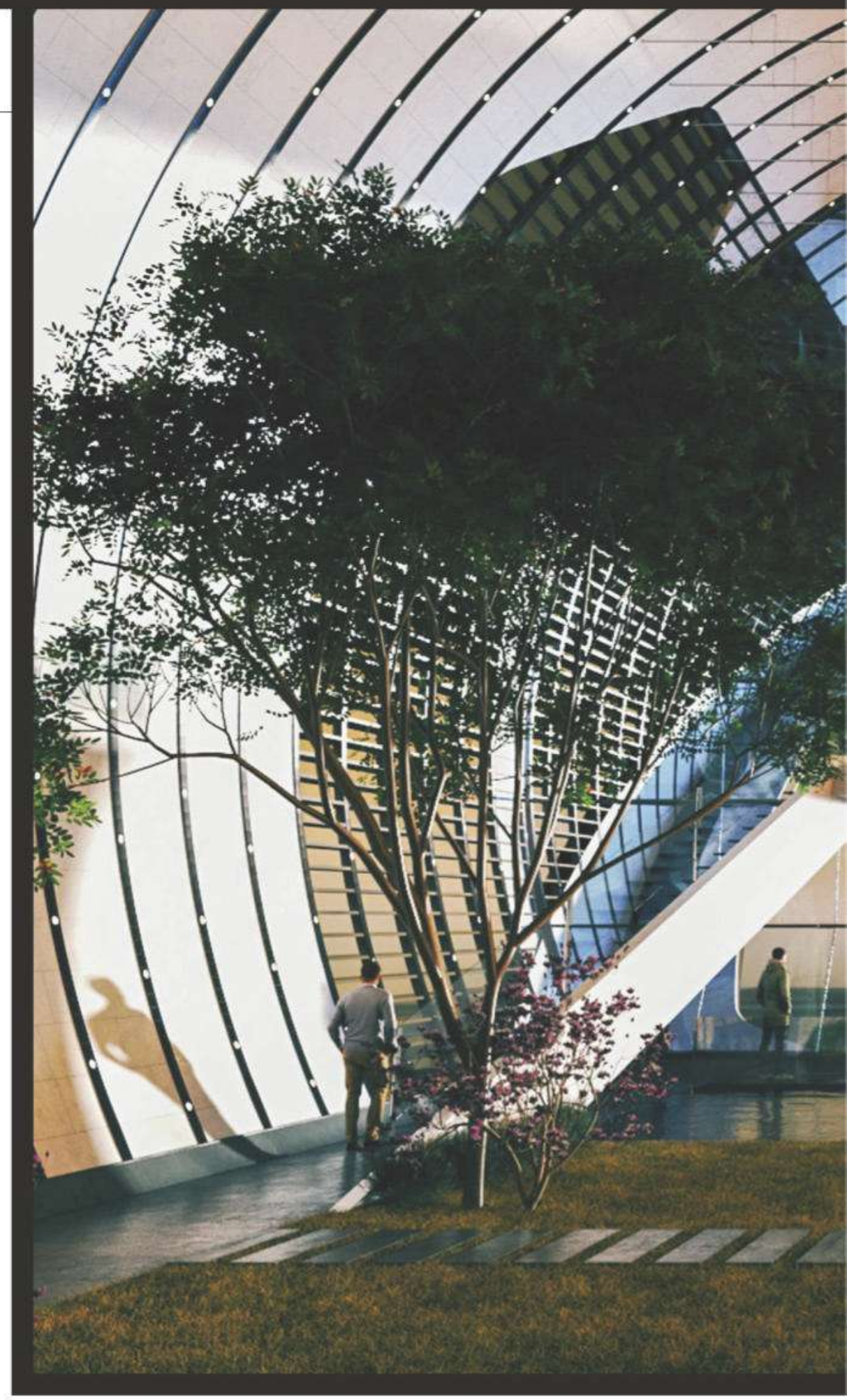
HOW TO BUILD A MARTIAN MEGA CITY

WITH MORE MISSIONS REACHING THE RED PLANET, A HUMAN LANDING GLINTS ON THE HORIZON. BUT WHAT COULD THE FIRST PERMANENT MARS METROPOLIS LOOK LIKE? WELCOME TO NÜWA CITY

WORDS: DR STUART CLARK

ILLUSTRATIONS: ABIBOO STUDIO

Nüwa City, designed to be home to between 200,000 and 250,000 citizens, is named after Nüwa, creator and protector of humanity in Chinese mythology



There can be no mistaking that interest in Mars is growing. Last month, three brand new spacecraft arrived at the Red Planet. The first was the UAE's Emirates Mars Mission, also known as Hope, which entered orbit on 9 February to study the planet's atmosphere. Just days later China's Tianwen-1 settled in, and is now getting ready to deploy a lander that will carry a rover to the surface in May. The third visitor, NASA's Perseverance rover, is carrying equipment to look for the chemical traces of past life.

However, it may just be the UAE's mission that history remembers as the most significant. It is nothing less than the first step in the country's stated ambition to establish an international human settlement on Mars by 2117.

And it's not just the UAE that is thinking about living on Mars.

In February 2020, The Mars Society, an organisation dedicated to the human exploration and settlement of the Red Planet, launched an international competition to design a Martian city. Entries came from 175 teams from more than a dozen countries.

"Reading them, I was struck by the ingenuity displayed by the teams in coming up with extremely clever technical, economic and aesthetic solutions to the problems of designing a practical and beautiful Mars City state," says Dr Robert Zubrin, founder and president of the Mars Society.

One of the teams that entered was the Sustainable Offworld Network (SONet), a community of professionals in the academic and private sectors dedicated to the development of sustainable human settlements on other worlds. Their entry: Nüwa city.

THE MARTIAN MINDSET

Nüwa is a Martian city made of tunnels built up to 150 metres deep into a cliff face. The tunnels would house residential and work areas, as well as urban orchards and green domes. Like communal gardens in cities today, they would include plants, animals and even small bodies of water. As many daily activities would be completed below ground, these lushly planted domes are designed to provide a psychological lift for colonists, offering spectacular views out across the Martian terrain.

What made the Mars Society challenge stand out was that it wasn't asking the teams to determine how to make a scientific outpost for an extended but ultimately temporary habitation. Instead it was asking specifically for a 'city state' that would be capable of housing a million people, providing schools, shops, hospitals and even facilities to process the dead.

The city also needed to be self-supporting as much as possible. It would have to produce all the food, clothing, shelter, power, consumer products, vehicles and machines for a million people. With Earth so far away, it would only be possible to import a small amount of key components, such as advanced electronics.

"The approach was very different to a temporary settlement," says architect and ➤

ABOVE As it will be a permanent residence, extra care was taken with Nüwa to provide for the inhabitants' psychological wellbeing. This is the view through a Martian green dome, and out across the Martian planes.

RIGHT The cliff tunnels are just one part of Nüwa city. On the cliff top, agricultural modules and solar panels are situated. Further away is the city's nuclear power station. Down in the valley is the rocket pad for new arrivals.

“THE TUNNELS WOULD HOUSE RESIDENTIAL AND WORK AREAS, AS WELL AS URBAN ORCHARDS”

urban designer Alfredo Muñoz of Abiboo Studios, who also serves on the SONet board.

In a temporary base, where a limited number of people live for months, or even years, doing their work and then returning home, the only real concern is keeping them alive. But somewhere that is going to be home for the rest of their lives is a different matter altogether. It required thinking about a much wider variety of issues.

"We started thinking, 'Okay, how do we ensure the right psychological environment to ensure that people are having a happy and enriching life? How can we create a beautiful experience and a life around the community in a place that is pretty harsh?" says Muñoz.

This meant Nüwa not only had to protect its inhabitants from the deadly Martian climate of temperatures as low as -103°C, but also allow a new civilisation to flourish. In other words, a lot of planning was needed for the project.

"HOW DO WE ENSURE THE RIGHT PSYCHOLOGICAL ENVIRONMENT TO ENSURE THAT PEOPLE ARE HAVING A HAPPY AND ENRICHING LIFE?"

CELESTIAL CITY

Nüwa city was designed by a 35-strong team that worked for four months to perfect the concept. It would be the capital of five such cities spread across the Red Planet, each one capable of sustaining between 200,000 and 250,000 people. The SONet team even identified the places where Nüwa and its sister cities would sit on Mars: a site located 225,000km from the extinct volcanoes of Mars' Tharsis region, near the planet's equator. The cities would be separated by a couple of thousand kilometres,

ABOVE LEFT Crops will be cultivated in the agricultural modules in an atmosphere rich in carbon dioxide. With an 'air' pressure just one-quarter that at sea level on Earth, it will not be breathable for humans. Cultivation must therefore be fully automated.

ABOVE Green domes will be built where the tunnels reach the cliff face. Some of these green domes will function as parks, others will be used to run experiments to see if vegetation can be adapted to Martian conditions. All will feature views of the Mars landscape beyond.

RIGHT By building Nüwa city into tunnels in a cliff face, the habitation and work modules can be placed under layers of rock, shielding the citizens from the radiation that reaches the surface of Mars.

"WE COULD START NÜWA BY 2054, AND HAVE IT FINISHED BY THE END OF THE CENTURY, IF THERE ARE THE RIGHT RESOURCES AND WILL"

and they would be accessed by the Martian equivalent of a light railway. Only Abalos City would be further away. Located towards the Martian north pole, it would be the water-mining settlement.

You would be forgiven for thinking that building not one but *five* cities on Mars is somewhat overambitious. Key materials required for everything from rocket fuel to manufacturing need to be extracted from natural Mars resources. For instance, graphite and ultra-high-molecular-weight polyethylene (used for construction) can be obtained through atmospheric CO_2. Similarly, native sulphur found in deposits on the Martian surface can be used to create cement.

But to astrophysicist Guillem Anglada-Escudé, Institute of Space Sciences/CSIC, Spain, and the founder of SONet, once he broke it all down he realised that he was facing the same set of problems that city planners have on Earth with just one major twist. "Everything that you need to run a city on Earth, you need on Mars as well, the only extra thing you need on Mars is air," he says.

Quite a bit of air, in fact: the Nüwa designers estimate 187,500,000m^3 of it would be required to maintain the city's 200,000 inhabitants (about 240kg of oxygen and 490kg of nitrogen per person). The traditional approach to this problem has been to build vast domes that trap air. But for Nüwa, the team came up with the idea of building into a cliff face. Not only would this help them trap air in the 30-metre diameter tunnels and caverns they planned to excavate, but the cliff would also protect the residents from harmful solar radiation that can reach the surface of the airless planet. Plus, the cliff rock

BELOW Select citizens may be permitted to study the Nüwa valley in pressure suits containing enough air to sustain them for at least 10 hours. Due to the harsh night climate, this exploration will only be possible during day.

provides low-cost protection from the massive pressure difference inside and outside the city. The mesa at the top of the cliff is where the large solar arrays and a nuclear power station would generate the 37kW per citizen needed to maintain life-support systems. Areas for food production would also be based here, providing the crops that will make up half of citizens' diets (the other half consists of insects, cellular meat and atmosphere-revitalising macroalgae).

A NÜWA REALITY?

Construction of this 'vertical city' would take place in phases. The first 10 years is when there would be substantial input from Earth. This would be in the form of machines and components that the colonist workforce would use to begin the construction. At the end of the first decade, SONet estimates that the city will be home to 10,000 people. Colonists would be need to pay $300k for a one-way ticket to Mars and a 25.5m^2 residential unit. They would be required to become a member of the working force. Around Nüwa's 50th anniversary, the colony would become large enough that it could become an independent state from Earth.

"It seems realistic that we could start Nüwa by 2054, and have it finished by the end of the century, if there are the right financial resources and the right will," says Muñoz.

Yet at present, Nüwa city exists only on paper. However, the construction of a series of Nüwa demonstration facilities on Earth to test the concept and its various technological solutions is currently being planned. "These will be experiments not only on planetary exploration, but experiments on architecture, material sciences, biology, ecology, economy, people living together and their psychology," says Anglada-Escudé.

Reflecting on the Mars Society competition, in which Nüwa finished in the top 20, Zubrin says, "What moved me most of all was the glowing idealism of the teams in striving to define a new and better way for humans to live together in a new world. To be sure, the teams did not agree on the specifics, and their ideas ran the gamut from concepts that could be broadly described as social democratic to libertarian. But what they all had in common was a passionate commitment to the search for something better. What could be more important?" **SF**

by **DR STUART CLARK**
Stuart is the author of Beneath The Night: How The Stars Have Shaped The History Of Humankind (*£14.99, Faber*).

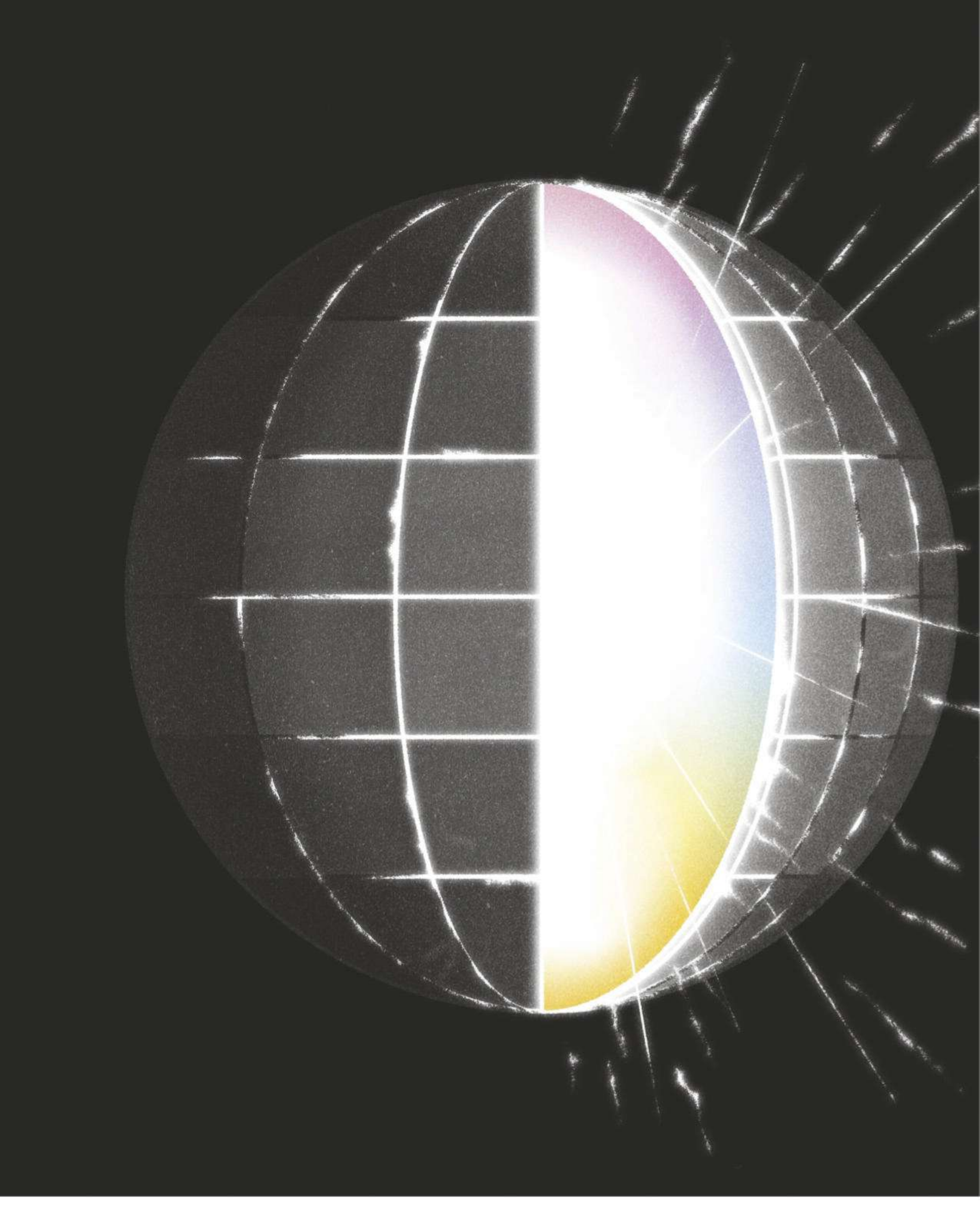


ILLUSTRATION: ANSON CHAN

CAN WE MAKE THE INTERNET GREAT AGAIN?

The rise of disinformation, online abuse and extremism has shown the web isn't the glowing network of knowledge, community and togetherness we once hoped it could be. Is there a way back?

The past 12 months have been a bumper year for the internet. Several billion people went online far more than they ever imagined. A US presidential election refocused the spotlight on disinformation, and how it might disrupt a democracy that was already shaken up by internet-fuelled alternative truths. We've witnessed the rise of cults, the demise of advertising, and the erosion of our mental health. By this account, it's not been a bumper year for humanity.

The pioneers of the internet never thought their invention would be at the centre of a global re-think. The internet project was famously funded by the US government, but its first use was to connect universities so they could share information. At its heart, this is what the internet continues to be used for: it creates connections between people to share news, photos of cats and countless memes. Over the last few decades, we've seen it evolve from a functional space of academic collaboration, to a place where people could find one another, to a battleground for hearts and minds.

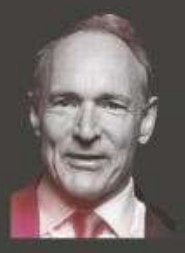
Computing historian Melvin Kranzberg once wrote, "Technology is neither good nor bad; nor is it neutral." This, his first 'law', is particularly applicable to the history of the internet. "Technical developments frequently have environmental, social and human consequences that go far beyond the immediate purposes of the technical devices," he wrote in 1986. He believed that many of the issues we have with technology are unanticipated outcomes from implementing them on a massive scale. They may produce benefits – creating rich connections, transforming economies, holding power to account, empowering the disenfranchised – but they can also expose the nasty stuff, like exploitation, cruelty and malicious manipulation.

We are at a turning point with the information architecture of our global world. After the year we've had, no one can claim technological ignorance. The COVID-19 pandemic forced us to embrace the tools and learn first-hand what the internet really is doing to us. With that knowledge, we have a choice. We can continue with a broken status quo, or we can change the future.

So, armed with enough knowledge, what do we have to do to take control and make the internet great again?

by **DR ALEKS KROTOSKI**
Aleks is a psychologist and writer. Her work focuses on interactivity and the online world. She is the presenter of BBC Radio 4's *Digital Human*.

Privacy: can we protect future generations?



PROF SIR TIM BERNERS-LEE
Computer scientist Sir Tim Berners-Lee is best known as the inventor of the World Wide Web. He is also a professor at the Massachusetts Institute of Technology (MIT), founder of the Open Data Institute and a recipient of the Turing Award.

In 1989, while tinkering with a system to share scientific notes, a 34-year-old CERN scientist named Tim Berners-Lee invented something that would change everything. You might have heard of it: the World Wide Web. Fast-forward three decades and 4.57 billion users later, he's on a mission to save his creation. Specifically, save it from a mounting privacy problem.

In the wake of the Cambridge Analytica scandal – in which the data of 87 million Facebook users was obtained without consent – Berners-Lee (now Prof Sir Tim Berners-Lee), has led numerous campaigns persuading governments to act. This notably includes 2019's Contract for the Web calling for new global web regulations. Its overall impact? Limited. However, after years lobbying others to take charge, Berners-Lee himself is trying to turn our online world upside-down (or, as he says, "the right way up"). His idea: Solid, a new system aiming to drastically decentralise the web. At its core, it's a platform allowing you to store your private information in Personal Online Data Stores (PODS) which you have full power and sight over.

While most sites and apps currently take your data and move it into a 'silo' out of your reach, Solid's vision is for these services to ask permission to use specific information from your PODS – permission that, crucially, you can remove at any time. In short: it'll be you who holds full control over your data, not Big Tech. While currently in its experimental stage, the platform is already trialling its system with the likes of the NHS, the BBC, NatWest and even the Belgian government.

But how far will Solid spread? And could it truly fix the internet's privacy problem alone? We put these questions to Berners-Lee.

WHY DOES ONLINE PRIVACY MATTER?

A lack of online privacy is not just about companies having your data, but how they use it to figure out what you'll click on. They're using it to make you click on stuff that you shouldn't be going on, making you follow clickbait.

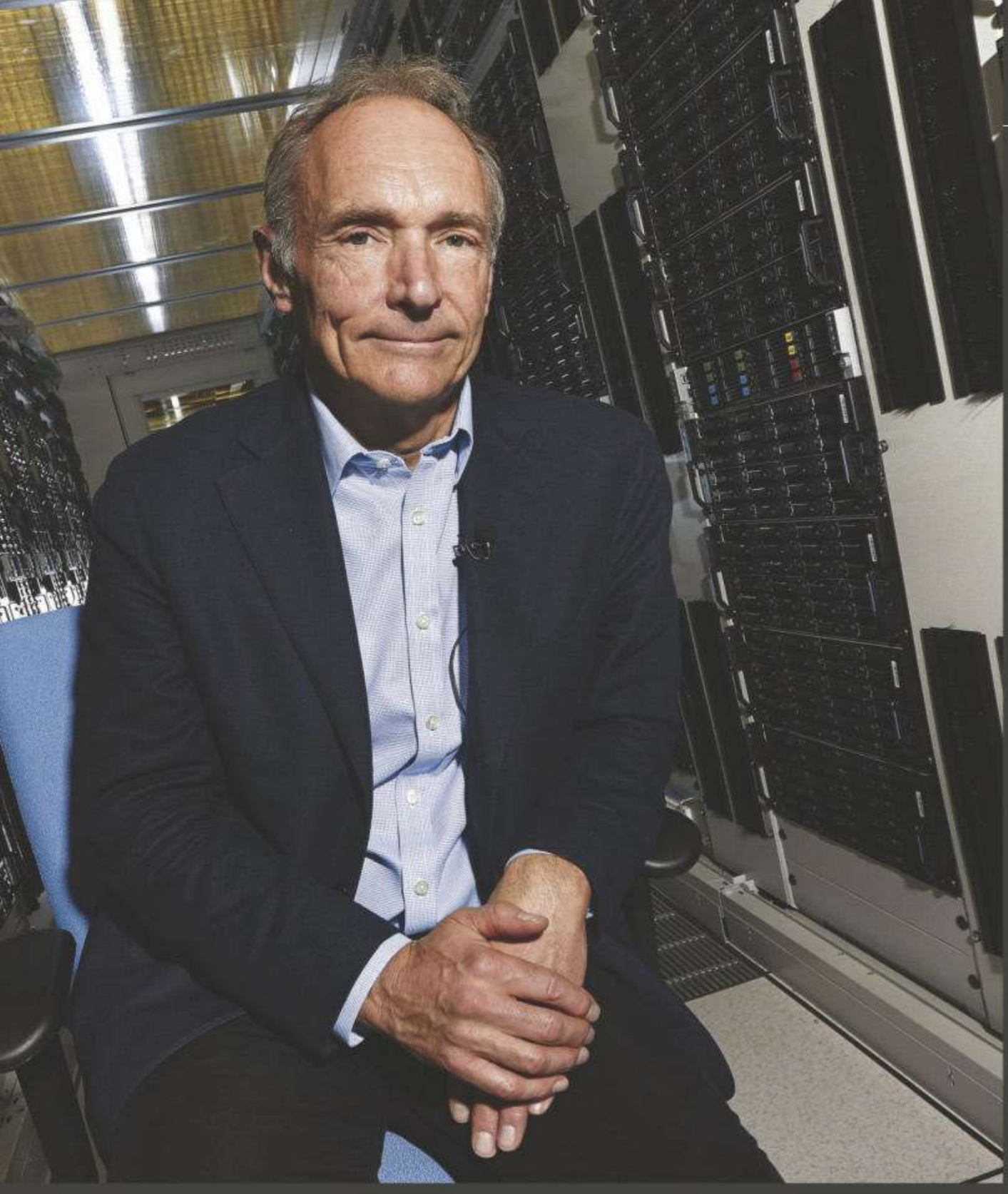
Using private information, they've built a profile of you and know exactly who you are. They know the lies they can spin you that could lead you up the garden path – things that may be political, commercial or criminal. And here's the bigger picture: people could misuse data about you to trick other individuals into voting for people that they really shouldn't – people that are not in their best interests.

HOW DOES IT FEEL TO KNOW YOUR INVENTION COULD BE ABUSED LIKE THIS?

Ten years ago I would have said that

CERN

"In a society that's best, you have to design technology with society at the same time"



humanity uses the web and if you look at humanity you'll see good and bad stuff.

However, at a certain point, around 2016 [circa the Facebook-Cambridge Analytica data scandal], I realised it's all very well if people I know are honing their bookmarks to have reliable, scientifically-based information, but there are a lot of people I don't know who have *very* different bookmarks. They could be reading all kinds of stuff that isn't true, and if it wasn't for democracy then I would have been happy for them to go on reading. But because they vote, we require more from the web – and certainly more from social networks. They have a duty, because we need informed voters who can participate in the debate.

BILLIONS OF USERS HAVE HAPPILY HANDED OVER THEIR DATA TO BIG TECH COMPANIES – DOESN'T THAT SHOW WEB PRIVACY ISN'T A REAL ISSUE FOR MOST PEOPLE?

Most people in their day-to-day lives aren't worrying about their privacy, but every now and then something happens like the Cambridge Analytica scandal. After things like that, people on the street may be worried that they're part of a system which is manipulating elections, for instance. And when they're offered more privacy-preserving alternatives they may become even more aware. Every time something horrible happens with one of the large social networks, a whole bunch of people move over to networks like MeWe that don't do anything with your data.

IS IT SIMPLY TOO LATE FOR US TO FIX THE INTERNET?

It's amazing how quickly things can change. Years ago people were worried that Netscape dominated every browser. And then Microsoft came along with Explorer, which became dominant. And then everyone worried about that until many other browsers emerged. And today people are saying "Oh no, everyone's using the same search engine!"

Well, problems can pass. In general, the web has been incredibly good at demonstrating that lovely though the walled garden might seem, the outside jungle is more valuable.

The dominant thing is always innovation and creativity.

DOES CREATING A SYSTEM LIKE SOLID FEEL LIKE BUILDING THE WORLD WIDE WEB FOR THE FIRST TIME?

Yes! It's really exciting because it's building a new system. But it is similar to the web in that it's really hard to explain what a world with a decentralised system like Solid will look like.

Solid is different from what we currently know because of its collaborative potential. For instance, if you are on a video call, you and whoever you're speaking to could be using whatever video call app you like. People struggle with this at the moment: the idea that you don't have to do a back end, that if you built a website you wouldn't have to make a database to store customer data. It's because PODS will provide a standardised protected data set.

CAN SOLID ALONE FIX THE INTERNET'S PRIVACY PROBLEM? OR DO GOVERNMENTS AND COMPANIES NEED TO ACT TOO?

In a society that's best, you have to design technology with society at the same time. For instance, GDPR [the EU's General Data Protection Regulation that minimises the data organisations can take from users] is incredibly compatible with Solid.

Solid will not only allow you to control who gets access to data, but you can also turn off that access with a switch. But if you hand over data for medical research, for example, there is no technology that can possibly make that data vanish if I change my mind. As a user, if I retract the access, I need rules and laws in place to make this happen. We need both rules and technology to solve this problem.

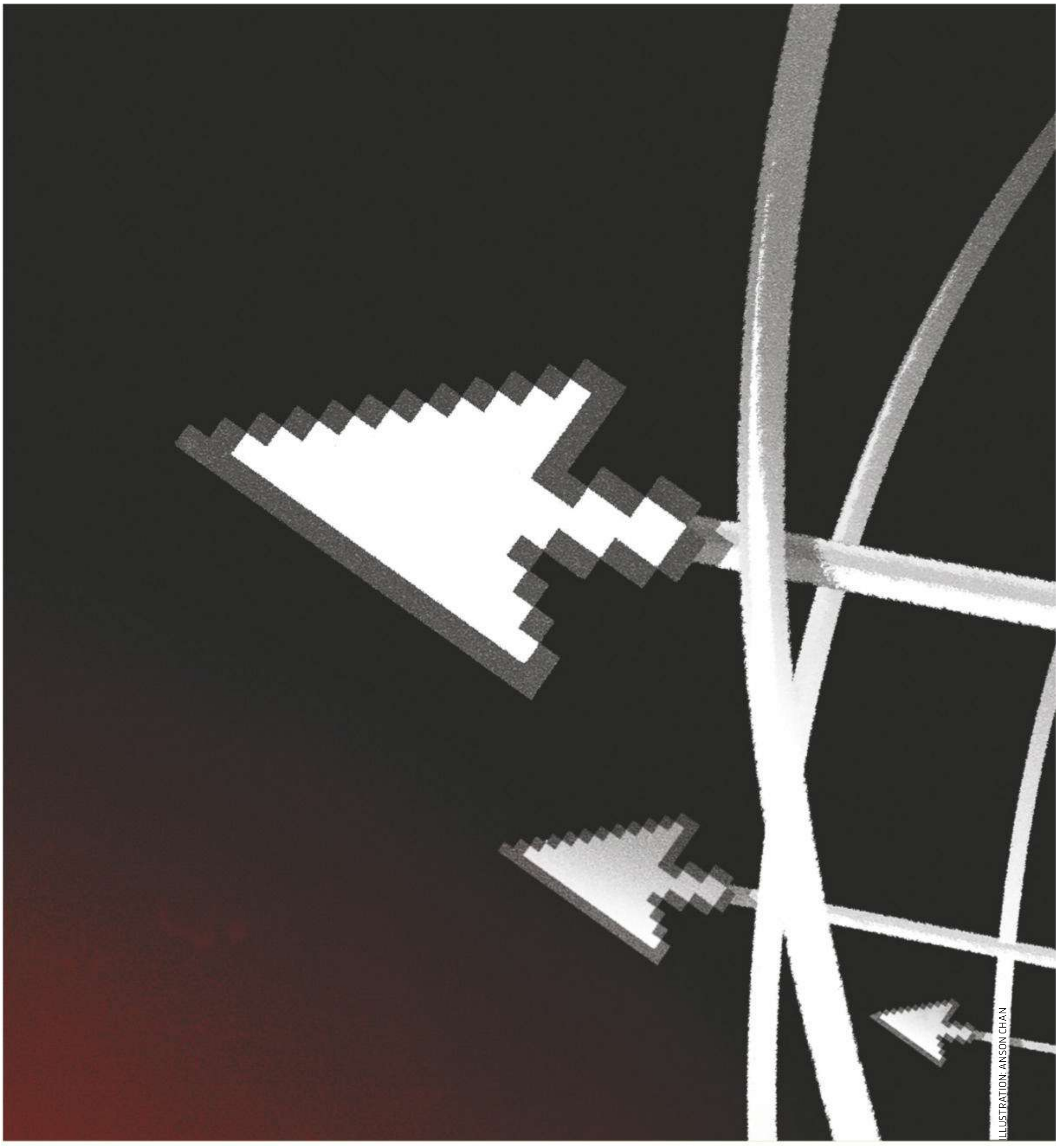


ILLUSTRATION: ANSON CHAN

Bullying: how to slay the social media trolls

TRACY CHOU
Tracy is a software engineer and diversity advocate. She is the founder of *Block Party*, an app to help tackle harassment on social media.

This is personal. I think my first experience of online bullying was probably 15 years ago when someone actually created a hate site dedicated to me during high school! But today the problem's grown out of control: the surface area over which you can be attacked is just huge and the incivility is overwhelming.

I interned at Facebook in 2008, I was at Pinterest when it had just 10 employees and I was the second engineer hired to work on Quora. My time at these places taught me that you can't just pull out content moderation from the platform as a separate problem. It's built in to how these communities work: poorly designed mechanisms open up the potential for abuse.

I also saw what the lack of diversity and inclusion in Silicon Valley meant. It's a place that has a habit of solving the problems of its own demographic. It seems like it's trying to figure out: "What did mom do for me that I don't want to do myself? Cook for me, do my laundry, drive me around." It's problematic to phrase it that way, but you get the point. If there aren't folks who have had to deal with the bad stuff, that means solutions to these problems aren't prioritised.

So, ultimately, I wanted to build the *Block Party* app to help everyone who deals with harassment and bullying on the internet. We didn't need sophisticated AI to build something helpful. The way *Block Party* currently filters out harassment or bullying is via simple heuristics [rules]. For example, there's an 'I need a break mode' where you won't see mentions from people unless you follow them or they're followed by the people you follow, they're a verified user or you've interacted with them recently.

We collect everything else and put it in a folder which you can review later. This way, you don't have to worry about missing out on anything but you do get to choose how and when you see things. This approach means we don't have to be perfect in classifying what's okay or not, with some kind of machine-learning algorithm that reaches whatever accuracy. And how do you even define 'correct': what's bullying and what's not? Each person has their own threshold, and it changes depending on how you're feeling. There are times when I'm ready to hear from the world and others where I'm just so exhausted with dealing with these people.

This strategy also means we can add other features. For instance, you can give others access to that folder, like friends or even the authorities, to look into the harassment. This is preferable to giving them my full Twitter credentials so that they see everything.

A lot of the current design of social platforms puts the onus on the victim to deal with the harassment. I did this Reddit AMA [Ask Me Anything] last summer and it ended up with 4,000 trolls brigading me. Reddit's response was that they don't condone harassment, and that I should report it. But I'm not going to sit there and report thousands of comments and accounts. It's frustrating and potentially traumatising to put that burden on the person who has to deal with the abuse. A sharing system like ours, with delegated access, means you can have others help you.

> "A lot of current design puts the onus on the victim to deal with the harassment"

We have a watchlist feature as well that lets you keep an eye on people. I once had someone who replied every time I tweeted and I didn't want to see it, so I muted him. But then at some point he escalated to physically stalking me and I didn't see it because of the muting. From that point on I had to regularly check his account to make sure I was going to be physically safe.

Ultimately, our goal is to get to a point where we won't just build on top of existing software for platforms like Twitter or Instagram, but provide tools for new platforms that will help them avoid the same pitfalls. Think of it like payment processing in apps – a start-up doesn't need to build that software, they just plug in a monetisation tool from someone else. *Block Party* could be that tool, and hopefully solve this problem for everyone.

Money: does the internet need ads?

TIM HWANG
Tim is a writer and a researcher. He is the author of *Subprime Attention Crisis*, a book about the bubble of online advertising.

Advertising was just one business model that people considered at the start. Google originally thought maybe 15 per cent of their revenue was going to come from ads; most of their money was going to come from licensing their search engine to corporate clients. It's funny; their search algorithm was the origin of programmatic ads. Now everything relies on ads.

In the old days, ads were sold the same way they're sold by a newspaper: you got a call from someone who wanted to buy a banner ad on your website. Google invented AdWords in the early 2000s to give people the tools to use data about what people search for. This model produced a Willy Wonka's Waterfall amount of cash for Google, and afterwards created the financial engine that is the core of what drives the modern internet experience.

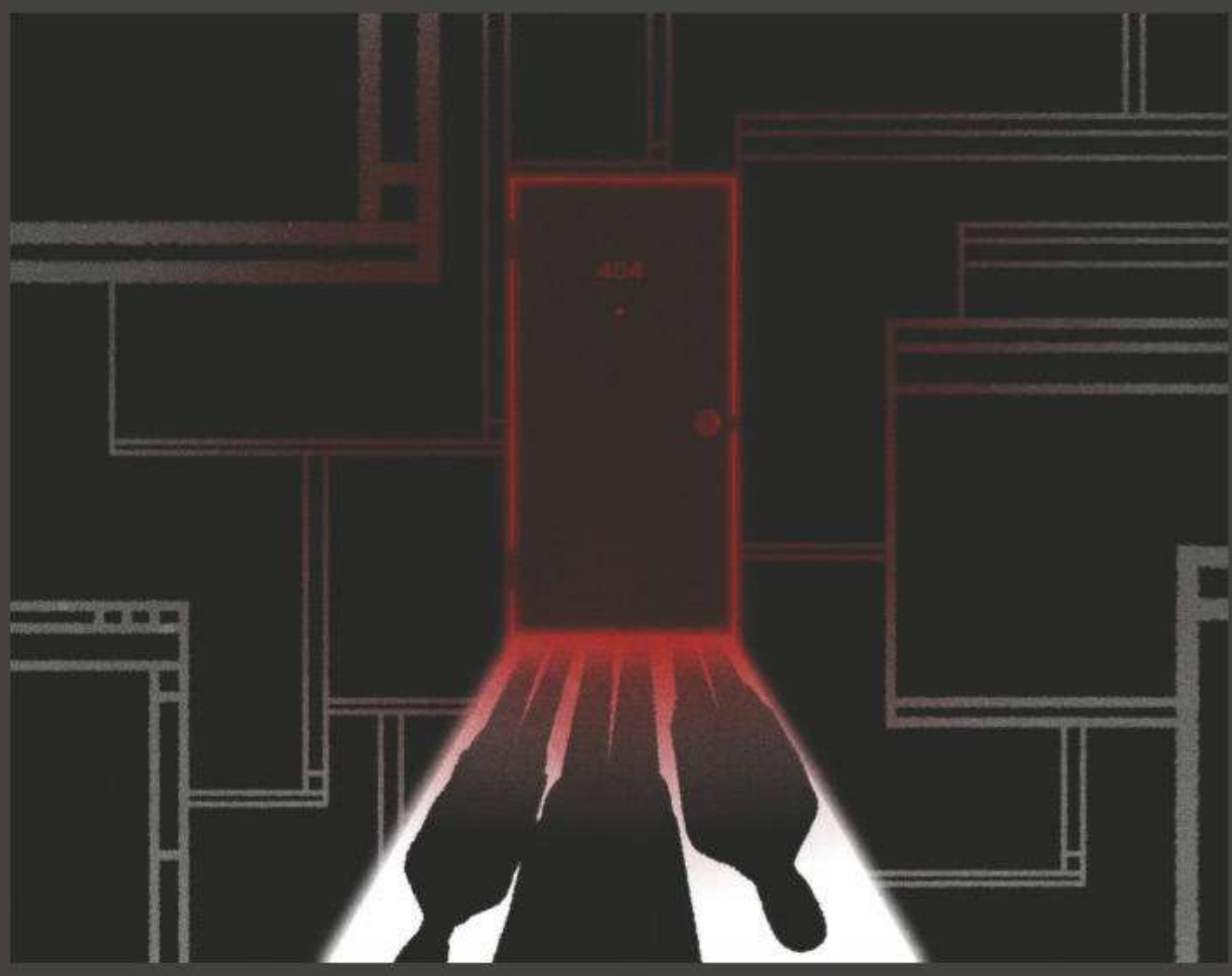
You start from this intuitive place: if I have all this data about someone, shouldn't I be able to get messages to them that will persuade them to behave how I want? There are two kinds of failure in this thinking: one is the failure of correlation versus causation. You often end up targeting people who would have bought the product anyway, and so the question of whether or not the ad gets you to change your behaviour is unclear. Second, everybody assumes the data you get about people is extremely accurate. But it turns out that that's flawed as well.

Advertising works, but its effect is so limited and small that in order to figure out whether or not it actually makes a difference, you have to conduct these enormously expensive experiments. A few years ago, Procter & Gamble, one of the biggest advertisers in the world, decided to cut $200m from their digital ad spending budget. The result was nothing changed at all – they sold the same amount – which asks what that $200m is being spent on. Advertisers say to regulators, "don't take my data away because if you do, the ads will become less effective and you'll destroy our market." But then we know nothing happens. Suddenly this begs the question, what have you been collecting all this data for this whole time? The problem is that programmatic advertising generates money quickly. It's difficult to imagine an alternative monetisation model that has the same pattern. It's like the scene in *Indiana Jones* when you have to replace the idol with another idol of the same shape and weight.

The bubble has to pop at some point. Look at the history of every other market bubble and it has exactly the same phenomenon: the underlying value of attention captured by advertising is declining. Advertising has allowed us to kick the can down the road on some difficult questions. Are we okay with an internet that grows slower and is more expensive to access? In a world where everybody needs to subscribe to a search engine, should it be public or should the government subsidise access? What about a social network? A lot of alternatives are better from a social standpoint, but they may not grow in the way that Silicon Valley is used to growing.

An internet that doesn't rely on advertising means we'll see more innovative business models. Some of them will benefit content creators, others will benefit companies. Maybe some of them will benefit the public. It will change the nature of the internet, and that'll take some getting used to.

Whether you're a technology believer or a technology critic, you have to believe in the efficacy of the technology, and a lot of our critiques of the technology give this myth a power it doesn't actually have.



Extremism: how physics can stop radicalisation

DR NEIL JOHNSON

Neil is a professor of physics at George Washington University in Washington, DC. In 2016, he and his colleagues published a paper in the journal *Science* that used complex models to map the global network of extremist groups online, leading to what they describe as the 'gelation' theory of extremism.

"I started researching extremist activity online with an Intelligence Advanced Research Projects Activity (IARPA) competition in 2011. The competition was: given that you know publicly available information, what can you predict about future events in the real world? At that stage, we were looking at Twitter. You can [now] hear the equivalent of Twitter from the guy standing with a megaphone outside. Everybody stops and takes selfies, and it attracts attention, but I've never seen anyone go, "you're right, you've changed my thinking". That happens in other areas like communities online where trust is built. That doesn't exist on Twitter.

In 2014, a Russian speaker in my group hit upon activity around Islamic State (ISIS) on V.contakte, the Russian social media platform. We tried to find them on Facebook, but Facebook had already shut them down. V.contakte, though, would only occasionally shut them down. That was interesting, because if they'd let them just go and not interrupted them, then ISIS would have grown into one big blob of ice – easy to get rid of. But they didn't. We traced the ISIS communities as they formed a little group here, and a little group there. I think of it like bugs in the yard. You're going to disrupt them if you stand in one corner with a shoe and hit them one at a time, but you're not going to stop them. It's like deplatforming. Sure, there are some that just won't get their act together afterwards, but they'll still find one another. And that's how we came up with the gelation theory of online extremist support.

The idea is that people who appear to be different from one another can 'gel' into hate groups online. It's not the obvious hate communities you want to worry about and shut down. For every one of those there are about 5 to 10 communities linked in to them. The ISIS community never called themselves 'ISIS Online', and they never showed the flag on their pages. Extremist organisations go through groups devoted to pet lovers, parents, people interested in alternative health. They target specific words and titles. That's the bait. Those sites are watched by hate groups, who then direct recruits to where the core discussion is – usually on a private server or an encrypted site. That makes them hard to track, and it makes them resilient to efforts to stop them. Facebook have hit a lot of the communities that we would call 'the bad ones'. But they've missed the other, less-obvious communities. But we don't have a map to see where they've intervened and why it isn't working.

The links between people, groups and clusters change all the time. Hyperlinks appear and are taken down; a network can look one way one day, and different the next. I need to know how these clusters connect and how they help certain content survive and get more exposure. I need to create new physics that can model how these communities behave. Then if we can understand and predict the dynamics of these networks – like we would a cluster of cosmic dust, or a glass of curdling milk – then we can see where intervention can take place to curb extremism.

The future of tracking extremist clusters isn't machine learning or AI. Humans will find ways to work around the bots. But it is some combination between people and machines. It's a work in progress. Humans have intuition. Nobody's built a machine with intuition. Yet."

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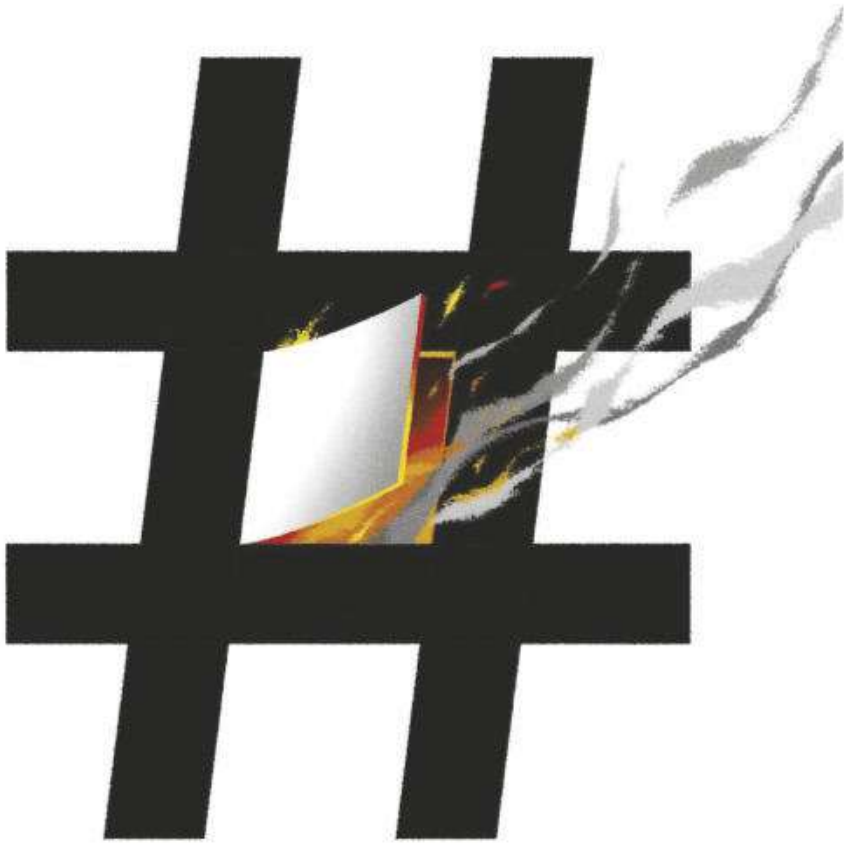

Polarisation: the tools that can smash our echo chambers

DR SANDER VAN DER LINDEN
Sander is a professor of social psychology in society. He studies the psychology of social influence, risk, human judgment and decision-making.

"There are two interesting debates here, and one is whether or not social media causes people to become more polarised and extreme. And that's a difficult question to answer. The easier question is whether or not social media acts as an amplifier of existing divisions in society. What you do see is that it clearly amplifies existing tensions through mechanisms that are now well-established in research, including echo chambers and filter bubbles that really work against – rather than with – people's psychology.

Behind the scenes, there's an algorithm that filters the information according to your click behaviour. So the algorithm takes these existing biases that are not that destructive on their own and puts them in an environment that's harmful for the way that people think about information and social reality.

Those mechanisms built by those echo chambers contribute to extremism and polarisation. Some good studies show that if you put people in those type of environments, they become more polarised over time. They become more extreme.

Ultimately, my sense is that this is a design question, that social media was not designed not in a way where people were thinking, "Okay, how do humans interact with technology, what could possibly go wrong here?" It was designed to maximise engagement. And that's really still the main currency. Polarisation results in flame wars, more sharing, more yelling and that all counts as engagement to these platforms. So what happens is that the more polarisation occurs, the more activity there is, the more engagement, the more ads make money, the more social media platforms make money.

There are solutions and people have tried these things, but it's not straightforward. One solution from social psychological theory, for example, is that when you expose people to the stereotype or the other group, they become more empathetic. But we know from research that's not sufficient in itself. If you expose people more to the views of others in social media, they can become more antagonised than they were before.

But what would I do? I think that it's so surprising that social media companies don't want to be arbiters of truth and they don't want to moderate. But since the beginning of the internet, there have been moderators. And I think one of the things that worked really well at the beginning of the internet, especially on chat forums and blogs, was that we had moderators who were quite strict about rules of engagement.

I think what social media companies need is an honest manifesto of rules for positive engagement and to enforce those rules. And those rules shouldn't only be decided by social media companies, but probably also the public and other stakeholders so that jointly we can devise a list of rules for positive interactions. That might include banning people with a history of attacking other people on social media, banning people who use tactics to try to get people riled up.

In a lot of our research, we've uncovered six broad manipulation techniques that people use to influence other people. One of them is polarisation. And there's certain language and tactics that you can use to try to drive a wedge between two groups. You can then try to detect that language and set up a set of rules so that you can have justifiable criteria for then deterring that.

Another thing is that people currently can't edit what they write. They don't have an opportunity for improving what they want to say. I think it's only human that people sometimes get angry and post something in the heat of the moment. It would be great if it was designed in such a way that people have an actual opportunity to correct themselves. You can be nudged, and the social media platform could say, "Listen, this is not a productive conversation. We're going to give you the opportunity to rewrite this in a more constructive way. If you don't, then we're going to have to remove this content."

I think social media companies would have to sit down with behavioural scientists and design a platform that not only has the technology, but also insights from the social and behavioural sciences on how to engage people in the right way and how to disincentivise polarisation and other negative processes. I do think it's possible, but it would be a radically different platform.

Mental health: social media has teeth, but how can we decide if it needs to be tamed?

PROF ANDREW PRZYBYLSKI
Andrew is an experimental psychologist at the Oxford Internet Institute. He studies how people interact with virtual environments.

We've had waves of panic around technology for decades, whether it be comic books or video games. Now it happens to be social media. And the fact of the matter is that parents and teachers, who are trying to raise their kids in the face of these panics, are being poorly served by the government when it comes to getting meaningful advice.

It's not that social media is good or bad for people. It's that the science of social media and mental health is broken. We need to do research, but we shouldn't be approaching it from the perspective that the world is ending. We need to be curious and open to the possibility of its effects, positive and negative.

For instance, in recent years, we've learnt, pretty conclusively, that violent video games don't cause real-world aggression. There's nearly a perfect negative correlation between youth crime and the sale of violent video games globally. And when we revisit some of the studies from the early 2000s that were heralded as reasons for regulation, none of their findings are replicated.

What makes things trickier when it comes to social media is, first, that the social media companies control the data, so it's much harder to study, and second, that it's the focus of the current panic. We know face-to-face bullying is much worse for young people in this country than cyber bullying is. But cyber bullying sucks all the air out of the room when you talk about victimisation in adolescence.

Put it this way, if I wanted to study bullying in 1980, I could go to a school, a playground, the local bowling alley, and I could basically capture a snapshot in the life of an adolescent. If I want to study bullying in 2021, I couldn't get a full picture of exactly what's happening because the social media companies hold all the data. Bullying online might not be any worse than it happening face-to face, but if it's happening behind closed doors I can't study or understand it.

But that doesn't stop people claiming that cyberbullying causes suicides, even though there's no evidence to prove it. You look at reasons why young people take their lives and it's test scores or exams, it's someone close to them taking their own life or it's drug- and alcohol-related. Those are the three main attributable causes. There's no evidence that social media is part of any of them. Now, I can either adopt false confidence and tell you social media might be a problem (and possibly drop the word 'might' for greater impact – and there's an entire cottage industry that tries to do that) or I can be honest with you and say I don't know because scientists like us can't see over the walls of the social media companies.

The danger for policymakers or parents is that if you pretend that social media is a problem, without having evidence, and you take steps to regulate it, the intervention could end up being really bad for young people. You might be taking away a lifeline for vulnerable kids or deprive them of their human right to play, which is morally reprehensible at the best of times, let alone during a pandemic. So that's why I'm not going to tell you that I know social media is bad.

It's perfectly reasonable for parents and teachers to be concerned about social media, but it's out there, it's unavoidable and young people are going to encounter it sooner or later. So what would you rather do: keep them in the dark and leave them ill-equipped to deal with it or let them learn about social media with your help and support? It's a little like learning to ride a bike. Bikes can be huge fun to ride, but you can also hurt yourself on them, which is why you don't just give your kid a bike and a helmet and wish them good luck. You help them learn to ride.

Similarly, with social media you need to keep the lines of communication open so you're not asking your 14-year-old daughter to choose between telling you someone scary is messaging her or losing her phone. You need to treat it like anything else that can hurt you, but can also connect you.

Whether you're a grown up or a kid, ask yourself why you're using social media. Is it because you want to, or because you feel you have to? It doesn't necessarily matter how much time you spend 'doomscrolling' on Twitter or dancing on TikTok, but if you're doing it because you feel you have to and it's making you unhappy, you may want to try and stop.

"Whether you're a grown up or a kid, ask yourself why you're using social media. Is it because you want to, or because you feel you have to?"

ILLUSTRATION: ANSON CHAN

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Disinformation: can we slow the tide of fake news?

NINA JANKOWICZ
Nina studies the intersection of democracy and technology. She is the author of *How To Lose The Information War: Russia, Fake News, And The Future Of Conflict.*

Domestic disinformers in the United States are probably the best in the world at creating and spreading disinformation. They don't really have to launch a campaign: they just plant seeds that grow with the infrastructure that exists online, and that are distributed with the help of the acolytes they've created. They partner with influencers who launder the messages for their followers to consume. Pair that with microtargeting – sending really specified pieces of information that they learn about us using things like Facebook groups combined with the public voter file that shows how we voted, what our issues are, who we care about, what we've donated to – and it's much more effective than anything Russia or China could do. I mean, they're good at following events and understanding what's going to be the meme *du jour*, but in terms of the level of disinformation that's currently being produced and spread, I don't think they could hope to achieve something like this. It's endemically American.

It's really hard to regulate the internet. This is perhaps the most complicated regulation that any democracy has ever pursued because of the ways that the internet has become enmeshed in our lives. It touches commerce, elections and freedom of speech. How do you disentangle all of that to create regulation that works for democracy? And should that be the government's job?

I've been thinking a lot about TikTok lately, the way it works, the way it is so ultra-personalised. You can't really do an influencer campaign on TikTok. You can't pay for something to go viral. You also can't create a fake account and expect something to go viral. TikTok is dedicated to being the last happy corner of the internet. And because there are so many teens on the platform, the people at TikTok are not reserved about taking content down if they think it violates their policies – things that are blatantly false, or harassment. But TikTok is a private company, owned by a Chinese businessman. They make their own rules.

Certain countries need to deal differently with regulatory questions than we do in places like the UK and US. The Ukrainian government subsidises their telecom companies, along with access to all the main apps. And so, when we say we're going to quit Facebook, that's nice for us, but in Ukraine they have a subsidised dependence on social media platforms that we don't. If we regulate, how are people in these countries that depend on these platforms for everyday, free communication – everything from baby pictures to work stuff to government staff – going to operate?

I used to use the term 'media literacy', but now I talk about 'information literacy'. Being information literate is broader than understanding how social media platforms work and how they target you. It's about the whole ecosystem that a consumer of information online needs to understand to have the full context, like why am I being targeted with this?

In terms of how we fight this, there's no easy solution. Fact checking people individually doesn't work. People tend to stand their ground when they see something that tells them that they're wrong. I've found that getting into a conversation has some success. Ask them, "Why do you believe this article? What appeals to you about it?" Understand where they're coming from and then hopefully equip them without saying, "you're wrong." Instead, we can say, "I know you care about child trafficking. Here is a better source than that." And then, over time and with better evidence, they come to change their minds.

The emotional approach takes so much more time and energy, but it's what you need to do to counteract disinformation online.

Breaking up the power: does the internet's future have to depend on a handful of megacorps?

"If you really want to make the internet great again, then you're suggesting that there was some moment of greatness. And I'm old enough to remember what that moment was. It was in the early 1990s, where the internet was a place where people brought their very best selves. And they wanted other people to think of them as articulate and having good ideas, and the whole point was to construct better approaches to everything. We were having discussions, and trying to figure out how to do government better, how to do economics better, how to understand physics and space travel and everything.

To use the internet, you had to sign a digital agreement saying you would use it for research and non-business purposes only, that this was like a public park. And because of that, it engendered a collaborative, cooperative, prosocial intellectual spirit. But when the internet was opened up to commercial interests, then the objective was to use these platforms to make as much money as possible. Unlike most internet applications, which were about communication and sharing, the web looked more like television. And the way television understood how to make money was to get people's attention and sell them things. You got companies like Google, Facebook, Yahoo! and Amazon taking something that's like a turbo-charged television as they saw it. So people compulsively clicked and bought more stuff and revealed more about themselves. This is not good, because when the object of the technology is to extract as much data, money and fear as possible, it makes people less happy and productive than if you're optimising a technology to enhance our ability to communicate, collaborate and cooperate with each other. The big platforms made more money by antagonising people. And that's because if people actually spend time with each other making love or playing cards or something, the megacorps lose engagement and money.

I always thought it was a stupid idea to put businesses online. The internet was like a play space – it was a bit like a fantasy role-playing game or a rave. And all of a sudden banks and companies are coming in to do fantasy role-playing. The GameStop and AMC story is really interesting: it shows one of the ways that we get the internet back is by playing online. The kids did a short squeeze on AMC or GameStop, with no intention of really making money – most of them just wanted to take down the bad guys. So one possibility is that we just go all in as activists and playfully hack people and start destroying the megacorps.

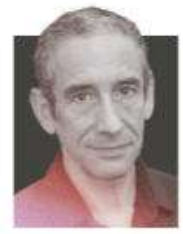
Another possibility is we just let them [the megacorps] have the internet. Now everybody's online, maybe we take back the real world.

And the other possibility is we make another net. It would be built on the original net principles, but maybe having two-way linking so it'll have a different dynamic. If everybody who links is linked back to, then it becomes a more of a genuine peer-to-peer thing than just having all of your value extracted and linked. To prevent the megacorps from misbehaving or dominating, it would require rules, so you can kick someone off if they don't behave.

The current net is almost killed anyway because of all the streaming media on there – the net is not a good place to be doing Netflix and Disney+. It's just too much bandwidth for the net to handle, which is why it's suffering in the COVID era. Imagine how fast a new network would be if you don't have these giant television companies trying to use it!

We could easily handle the entire internet as a peer-to-peer open web, rather than using these proprietary cloud services. We could be the cloud: everyone's computers joined as a giant torrent network. This would distribute all of the files, so all the stuff of the internet ends up on all our machines – not in the desert on the massive air-conditioned server farms of Amazon or Google or Facebook. The only reason you need those farms and all that is because of the massively inefficient way that this data is served to us.

The megacorps kind of sowed the seeds of their own destruction. There's karma. It will come back and bite you, which is what these big hedge funds are seeing now. They're like, "Oh my god, for all of our ultrafast trading, some kids on Reddit can actually cost us $5bn. This isn't right!" But that's the f**king internet. What did you expect? This is a play space. This is not a power space."



DR DOUGLAS RUSHKOFF

Douglas studies human autonomy in a digital age. He is a research fellow at the Institute for the Future, and founder of the Laboratory for Digital Humanism at Queen's College, City University of New York. He is the author of 20 books. His latest book, *Team Human*, is available now.

Curated by Dr Aleks Krotoski. Interviews by Dr Aleks Krotoski, Daniel Bennett, Alice Lipscombe-Southwell, Thomas Ling, Sara Rigby and Rob Banino.

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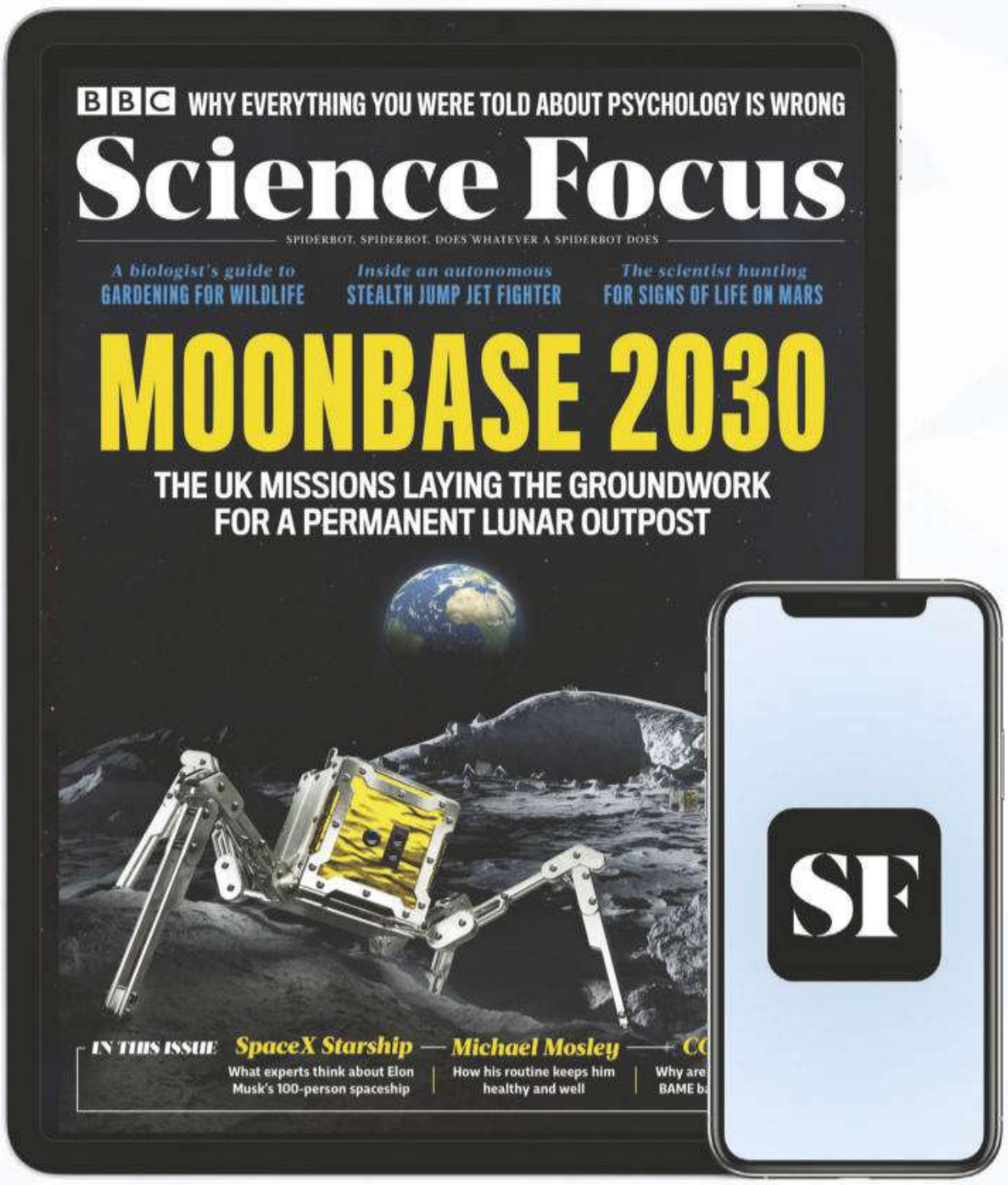
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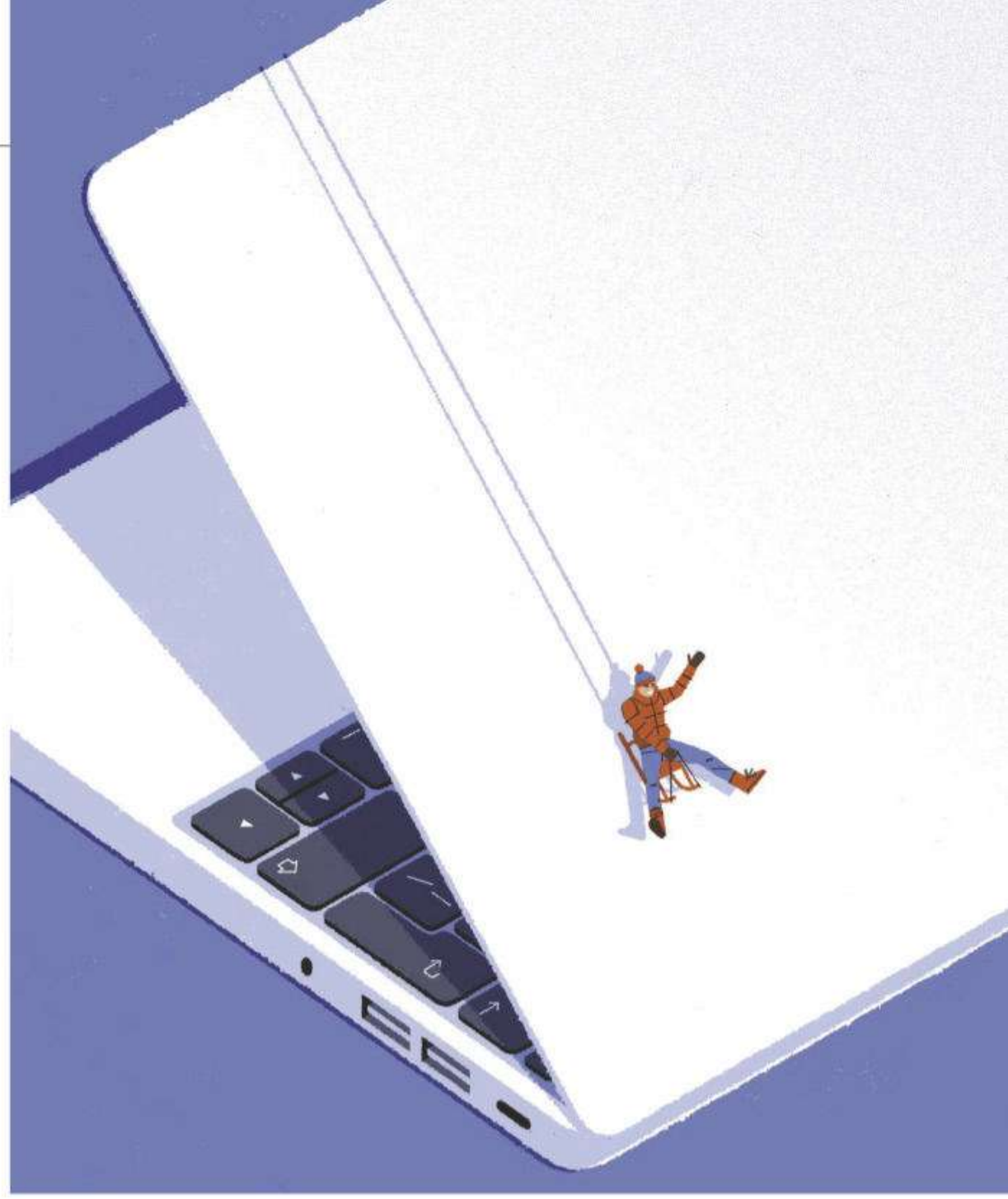
EMBRACE A SNOW DAY

This last year has been tough on everyone. We should make the most of an opportunity to frolic in the snow (or veg out on the sofa)



One of the unanticipated consequences of COVID-19 is that we can no longer justify the sloth we once enjoyed in idle moments caused by Acts of God. Snow days, leaves on the line – these once perfect excuses to sit in front of the telly with bag of Doritos have been stolen back into productivity by connectivity – and not just because we have digital access, but also because we've got really good at using it.

Offices that never imagined committing to remote working now expect employees to turn up (fully clothed) when transport is down. When plagues of locusts swarm, school schedules migrate online. In this new normal, Oz's Dorothy would have been expected to log in to classes while her house was sucked into the tornado's vortex. And that would have been a terrible mistake.

If, during lockdowns, you were one of the enviable people who didn't need to provide full-time care or have a job on the frontline, you might feel you've had enough days off. But emergency procedures are put into place for a reason. When I was at school near Washington, DC, we were sent home once due to the threat of a hurricane. While we didn't get hit, Hurricane Hugo caused more than $7bn of damage to South Carolina. When you got a day off, it was serious.

PORTRAIT: KATE COPELAND ILLUSTRATION: MATT HARRISON CLOUGH

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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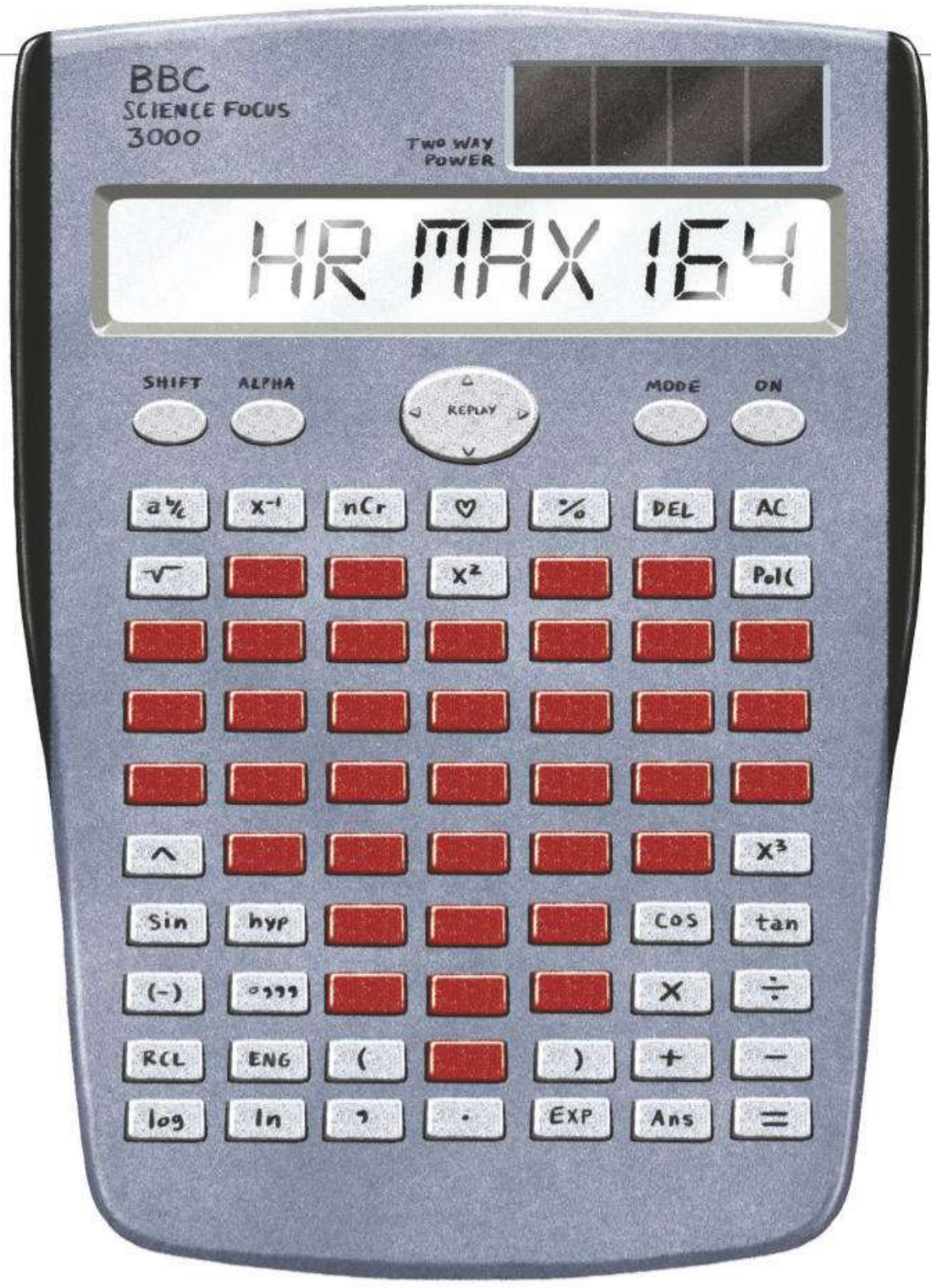
"We don't always need to use our technological solutions as a workaround for epic events, just because we can"

Obviously, this whole last year has been an Act of God, whether you've been locked down for the duration, or just some of the time. This epic event has broken our economies and our mental wellbeing. We had to come up with solutions, which we did – thank you, internet. The challenge now is to know when to apply those solutions, and when a moment warrants calling an old fashioned in-front-of-the-TV-with-a-bag-of-Doritos snow day.

Back in December, our kid's school was closed when a blizzard hit the east coast of the US. Our online school protocols were already in place because we'd been doing remote classes for three months. But rather than asking us to log our kids in for a new-normal day at home, the principal reminded us that this was serious. "This has been a hard year for everyone, including our children," he wrote in an email. "Many of the joys of childhood have been curtailed due to very necessary safety restrictions. However, playing outside in the snow, albeit with masks and social distancing, need not be one of these," he continued. "A snow day is a joy of childhood, and we should not let it be taken away from our students as a by-product of COVID-19."

We don't always need to use our technological solutions as a workaround for epic events, just because we can. They can normalise things that are big deals, and should be treated so. Calling a day off when Mother Nature interjects gives us a moment to reflect on the awesome thing that's occurred, and its impact on both our fellow humans and the infrastructures that keep 'normal' ticking over. **SF**



COMMENT

KNOW YOUR HEART RATE

With a few simple calculations, you can easily figure out how healthy your heart is

Your resting heart rate is a good measure of fitness and also a powerful predictor of future health. According to a study published in *The Lancet* in September 2008, patients with heart rates above 70 beats per minute are at greater risk of heart attack and hospital admission. With regular exercise you should see your resting heart rate fall.

Your resting heart rate is easy to find. Turn your hand so your palm is facing you. Use the index and middle finger from your other hand to measure it at the wrist, just below the thumb. Measure it when you're sitting down and relaxed, preferably first thing in the morning. Top athletes can have a resting pulse as low as 40 beats per minute. Mine is around 54.

The greatest benefits of exercise come when your heart rate is 60 to 70 per cent of your maximum heart rate (HRmax). So how do you measure that? The most direct way is to run or cycle as fast as you can for a couple of minutes, have a brief rest, then push yourself as hard as possible for another couple of minutes. Your heart rate will probably peak during the second burst. Don't try this if you have any doubts about your fitness.

"The heavier your body, the harder your heart has to work to supply it with blood"

When I did this recently, the highest I could get mine was 164, so my HRmax is 164. A less stressful (and safer) way to estimate of your HRmax is by using one of the formulas for calculating it, of which the best known is 220 minus your age for men and 226 minus your age for women. A more reliable version for both sexes is: HRmax = 205.8 - (0.685 x age).

On this basis my HRmax is 163, which is almost exactly what I found in practice. Knowing your HRmax will help you estimate how hard to push yourself during exercise.

Your HRmax will also help you calculate your VO_2max – the maximum amount of oxygen your body can use while exercising and a good measure of your aerobic fitness. The best way to measure your VO_2max is in a lab, but you can also use the Uth-Sørensen-Overgaard-Pedersen estimation: VO_2max = 15.3 x HRmax/HRrest

Since my HRmax is 164 and my resting heart rate is 54, according to this formula my VO_2max = 15.3 x 164/54 = 46.5 mL/(kg.min), which is excellent for my age.

So how can you get your heart rate down? Do more exercise and, if you're overweight, lose a few kilos. The heavier your body, the harder your heart has to work to supply it with blood. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor.* His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

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THE WOMEN IN HISTORY WE DON'T TALK ABOUT

Beyond the exceptional talents of Marie Curie, Rosalind Franklin and Ada Lovelace, it'd be easy to think that women didn't used to participate in science. But as science historians **Leila McNeill** and **Anna Reser** reveal to **Sara Rigby**, women have contributed to our understanding of the world, stretching all the way back to antiquity

READING ABOUT SCIENCE HISTORY, YOU OFTEN GET THE IMPRESSION THAT IT WAS EXCLUSIVELY MEN DOING SCIENCE FOR CENTURIES UNTIL THERE WERE A FEW SUPERSTARS, PEOPLE LIKE MARIE CURIE OR ROSALIND FRANKLIN, WHO BROKE THROUGH. WAS THAT REALLY THE CASE?

LEILA MCNEILL: It certainly isn't, and we can find women participating in science going back to antiquity all around the world. And one of the problems with looking at figures like Marie Curie and Rosalind Franklin is that they were anomalous in the sense that when they were making their discoveries, it was still very rare for women to be in higher institutions of learning, and scientific institutions in particular. And so when you're just trying to look for women in those spaces, those are the figures that tend to pop up. They're easy to find because institutions keep records and things like that.

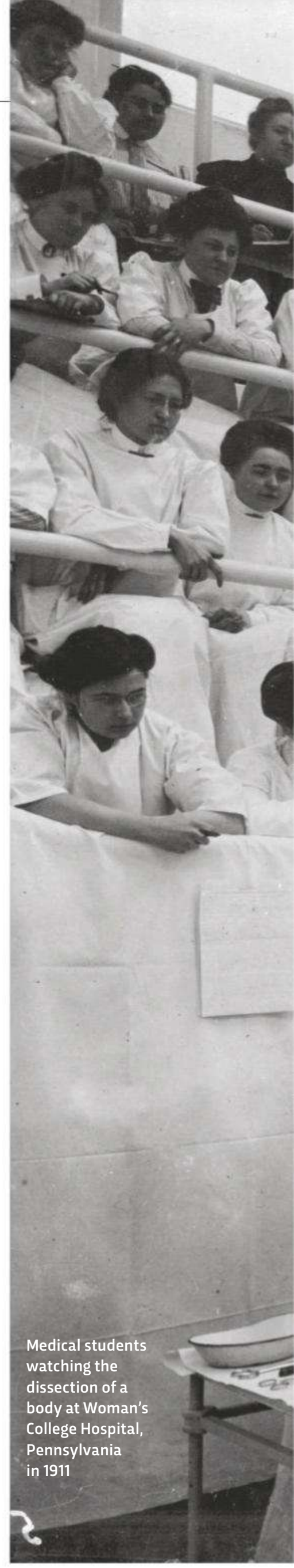
One of the things that we were interested in doing was looking beyond those institutions where formal records are kept, to see the different ways that women could have been participating in science on their own terms and in their own way outside of these spaces.

We find women doing this in all kinds of ways, going all the way back to antiquity. And one of the most common ways that we see women participating in medicine is as healers and midwives in various forms. We find that to be the case in antiquity all the way through the Middle Ages, up until the 19th Century when medicine was professionalised. At that point, it was taken out of the hands of women who were practising these things in their homes and their communities, and taken into that institutionalised setting where, again, that's where you start getting those unsung women in science, the ones who broke into that institutional barrier.

WAS THERE EVER A TIME OR PLACE WHEN WOMEN DIDN'T ENGAGE IN SCIENCE?

ANNA RESER: I don't think so. I think one of the things that we had to do for this book, and that I think we need to do more broadly when looking at the history of women in science, is to rethink what counts as science.

We use the term 'pursuing knowledge of nature' because institutionalised, formalised science didn't exist until the early-modern period in a way that people recognise. Before that, you're not really looking for science *per se* in those terms. But there are people pursuing knowledge about nature, ➔



Medical students watching the dissection of a body at Woman's College Hospital, Pennsylvania in 1911

GETTY IMAGES

and women can be seen doing that in every period that men were as well.

If we only think about science as something that happens in this broadly public collaborative way across the community of intellectuals, then you're not really going to find women doing that in a lot of spaces. But if you zoom in a little and look inside homes and communities, women are pursuing this knowledge in these spaces instead.

So instead of looking for women where men are, we look for them where they are. And in those spaces, you do find particularly, like Leila said, women practising medicine to care for their own families and their communities, but also sometimes to make a profession out of it. They might have been making and selling medicines, travelling around as a healer, things like that – and particularly midwifery and the care of pregnant women and babies.

WHY MIDWIVES AS OPPOSED TO DOCTORS? WHY WAS THERE A GENDER DIVIDE BETWEEN WHAT SORT OF MEDICINE PEOPLE PRACTISED?

AR: Well, it's a little bit complex. A doctor in the sense that we think of it now, like a physician, was not really a profession until the modern period – at least in the sense of having a special, formalised education and all these institutional bodies to which you can belong. The divide, I guess, between midwifery and being a doctor in the ancient world is much fuzzier than that.

LM: One way to think of it is that women cared for women, and that's more of the divide rather than midwife versus physician.

WERE MIDWIVES RESPECTED IN THE SAME WAY THAT PHYSICIANS WERE?

AR: Yeah, particularly in Ancient Rome. We have a lot of material from Ancient Rome about the profession of midwifery, and one of the things that we have a ton of are relief carvings of midwives at work, which are really cool. They used specialised tools. They had a particular kind of birthing chair that was in their possession; they would take the chair from job to job, helping women to give birth.

And even in the *Hippocratic Corpus* [a collection of Ancient Greek medical works, which includes texts about ethics, illnesses and diagnostics], there are writings by men that place midwives in this context of professional medical practice. For instance, Soranus [the Greek physician] writes about the characteristics of a good or ideal midwife, so there's some sort of idea of standard for the profession. His ideals were that she should be literate and versed in medical theory. Midwives were respected and were thought of as professionals who did a specific job and had specific skills related to that role. And we have lots of evidence of these midwives from that period.

"We have a lot of material from ancient Rome about midwifery, and one of the things that we have a ton of are relief carvings of midwives at work, which are really cool"

ABOVE Carving from Ancient Rome of a midwife helping a woman give birth

MANY WOMEN IN SCIENCE HISTORY SEEM TO HAVE DONE A LOT OF WORK IN ASTRONOMY. YET IT OFTEN SEEMS TO BE WOMEN WHO WERE THE WIVES OR SISTERS OF PROMINENT ASTRONOMERS. WHY IS THAT?

AR: I would say that for most of recorded history, that's the only way that women had to

get into those fields. So if we're talking about someone like Caroline Herschel, her brother William was an astronomer. He needed a housekeeper, so he brought Caroline to England to work in his house, and he just enlisted her to be his assistant, kind of without her permission.

William had his own observatory at their house in Bath. It is very expensive, to buy telescopes and to maintain them. Obviously, the Herschels were an upper-middle-class or upper-class family. They had plenty of family wealth. But that's not something that the women in the family would have had independent access to. So in order for her to have a space to work in, she worked in William's observatory.

In order for women to participate in, or at least get close to these formalised and institutionalised spaces for science, usually they would have to do it through a man who was connected to it. Often that would be the husband, or in Caroline's case, it's your brother.

HOW COMMON DO YOU THINK IT WAS THAT PROMINENT MEN IN SCIENCE HAD A FEMALE COUNTERPART WHO HELPED THEM AND MADE THEIR OWN CONTRIBUTIONS TO THE WORK?

LM: I think it happened a lot more than we have a record of. We're able to find out about [people like Caroline Herschel] because of what men said about them for the most part. So that, I think, brings into question how many women were doing this work where their husbands didn't credit them.

It was expected that the women would be the ones helping and the men would be the ones publishing. We do have plenty of evidence that wives and sisters were doing this work, but I think that there was a lot more of it going on than we have a record of.

WE'VE TALKED FOR THE MOST PART ABOUT EUROPEAN HISTORY. WHAT ABOUT OUTSIDE OF EUROPE?

AR: With the caveat that neither of us are specialists of China, there are a lot of records of women participating in medical practice in Ancient China. A lot of what we know about this comes from things that men wrote about women. And so, again, you do have to filter through these sources and read between the lines.

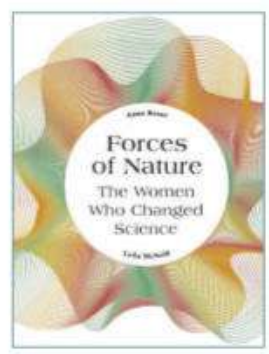
One of the fascinating things that I found when reading about this is that there are these kind of mythologised figures of 'grannies' that are these medical practitioners like herb sellers. The articles by men are cautionary writings about kind of wily women, medical practitioners that you should avoid because they're tricksters and they will do scams on you and sell you things that don't work. But that's still evidence of women who were medical practitioners: if men were worried enough about them to write them down, they existed. People knew about them. They were figures in public life that you would encounter. And so, you take the stories about these medical grannies with a grain of salt.

LM: This idea of women taking care of women is something that – even if it does seem kind of sexist – was a tradition that allowed women an entry into the modern, institutionalised practice of becoming doctors.

At the Woman's Medical College of Pennsylvania, they accepted students from Japan, from India, from Native American communities. And a lot of them went on and studied women's medicine, gynaecology and obstetrics – there was a need for that in their communities and in their own countries, since men weren't doing a great job at taking care of women. We have this long tradition of women taking care of women, and that became an actual argument for them to become licensed physicians. SF

ANNA RESER
Anna is an American historian of science and technology. She holds a PhD in the history of science, technology, and medicine from the University of Oklahoma. She is the co-founder and co-editor in chief of Lady Science *magazine, and her writing has appeared in various publications including* The Atlantic, Real Life, *StarTrek.com and Technology's Stories*

LEILA MCNEILL
Leila is an American writer, editor, and historian of science. She is an affiliate fellow in the history of science at the University of Oklahoma and the co-founder and co-editor in chief of Lady Science magazine. *She has been a columnist for Smithsonian.com and BBC Future, and her work has been published by* The Atlantic, The Baffler *and JSTOR Daily among others.*



DISCOVER MORE

FORCES OF NATURE: THE WOMEN WHO CHANGED SCIENCE *by Anna Reser and Leila McNeill is out on 20 April 2021 (£20, Frances Lincoln).*

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WARNING

Psilocybin is a Class A drug according to UK law. Anyone caught in possession of such substances will face up to seven years in prison, an unlimited fine, or both. More information and support for those affected by substance abuse problems can be found at **bit.ly/drug_support**

MIND-MENDING MEDICINE

BBC TWO

Coming soon to BBC Two, *The Psychedelic Drug Trial: A Cure For Depression?* Check *Radio Times* for details.

Scientific evidence for using psychedelics to treat mental health problems has been mounting for the last decade – but researchers and patients alike have been waiting for a breakthrough. Now, scientists are poised to publish a gold-standard, double-blind randomised control trial, pitting antidepressants against psilocybin, the key ingredient in magic mushrooms. Could this be the study that brings psychedelics to the NHS?

by **MOYA SARNER**

GETTY IMAGES

Leonie, 44, knew where her depression came from – but that didn't make it any easier to live with. Growing up in South Africa, where both her parents were violently attacked, left her with what she calls "a constant, low hum of insecurity and threat, almost like tinnitus." Her father died when she was 17, and in her 20s, she became her mother's carer. By the autumn of 2019 she had been on antidepressants for more than half her life, with barely a break.

The medication helped to stabilise Leonie during the most severe episodes that left her bed-bound, but in between she was advised to continue on a preventative dose. She experienced a relentless low-level depression: "It was almost more debilitating, because you're functional but only half alive. You're getting by and everything looks okay, but for me, that's a life half-lived." She tried four different selective serotonin reuptake inhibitors – the most common class of antidepressants known as SSRIs – as well as two varieties of therapy. The problem was, she says, that in her experience antidepressants numb you. "It's what makes you able to deal with the difficult feelings and carry on functioning. But if you're numb to your own pain, it's really hard to unpack it and explore it in therapy, make sense of it and file it in a different way. All you're doing is keeping it there under a band-aid."

Magic mushrooms contain psilocybin, which is showing promise as a treatment for mental health problems

GETTY IMAGES, EYEVINE

"Psychedelics come in and free everything up, it's a window of opportunity to think and behave in a different way, like a psychological rebirth"

By November 2019, she was desperate. "I thought, I've got to do something different, because what I'm doing is slowly killing me," she says. She came across an innovative new trial on Google, and she felt hope.

PSYCHEDELICS VS ANTIDEPRESSANTS: HEAD TO HEAD

For the last decade, evidence has been building to support the theory that psilocybin – the key psychedelic ingredient in magic mushrooms and some other Class A illegal drugs – could be an effective tool to understand how mental illness manifests in the brain, as well as a potential treatment. Controlled studies found it had few side effects, and left most people with depression experiencing improved symptoms, and most people with terminal cancer less anxious about death.

"I wanted to know how good psilocybin really is," says Robin Carhart-Harris, head of the Centre for Psychedelic Research at Imperial College London. That meant comparing psilocybin with the standard treatment for depression on the NHS: antidepressants. (In the three months to September 2020, these were prescribed to more than six million people in England.) It meant conducting a double-blind, randomised control trial – the most rigorous scientific method of evaluating an intervention, the gold standard.

Every participant – including Leonie – was thoroughly screened by psychiatrists and other mental health professionals and weaned off antidepressants before taking part. They were randomly assigned to one of the two study arms – the psilocybin condition, or the antidepressant condition – but were not told which. They knew they would receive two doses of psilocybin three weeks apart, but did not know if this would be a high or low dose. They also each had a pot of capsules to take at home, without knowing if this pot contained a placebo or escitalopram, a well-performing SSRI. Participants in the psilocybin

Psilocybin in tablet form

arm received 25mg of the drug. "That is a whopping dose, enough for a transformative experience. It could be profoundly blissful; it could be profoundly scary; whatever the flavour of it, it tends to be very, very intense," Carhart-Harris says. Those in the escitalopram arm received just 1mg of psilocybin – considered a placebo dose – and all would receive psychological support before, during and after dosing. And that, explains Prof David Nutt, director of the Neuropsychopharmacology Unit at Imperial College London, is what makes this trial a game-changer; "That's the real innovation – people didn't know what they got, so it was a much better controlled, much more scientific comparison."

SURPRISINGLY UNBROKEN

On the first day of the study, Leonie met with the two therapists who would be her guides. In a hospital room decorated with Himalayan salt lamps, artificial candles and fake plants, her therapists talked her through a visualisation of a deep-sea dive, which she describes as her "handrail" for the trip. "Your guides are your anchor, and you can always pull yourself up on them to get back to the surface. But the invitation is to dive deep, to go down to the spiky, dark, grimy, slimy bottom of the ocean to find the pearl," Leonie explains. The pearl, for her, was to get to grips with her depression.

The next day, she watched as the psilocybin was brought into the room in a beautiful ceremonial bowl, and took her dose. As she lay on the bed wearing an eye mask and headphones and listening to music, she understood the trauma of her life with new meaning. The music sounded discordant at first, and Leonie saw an image of her mother as "a limping duck, waddling along with a broken limb". The image encapsulated, she says, "my mum's process of dying, how broken she was, her limping through a very unfulfilled life, one I felt like I was repeating and not finding the point of it at all." But as the music's layers built up to a more expansive sound, "that broken discordant note that was my mother turned out to be a piece of the most exquisite, transformative masterpiece; all of a sudden, my mum's broken notes made perfect sense in the symphony."

Leonie finally felt able to see meaning in the loss, to reframe it, and separate herself and her life out from her mother's. In what she calls "a real moment of ancestral healing", she describes taking possession of her own life and mind: "I became this point in time; there was my mum, my mum's mum, and my mum's mum's mum, and I felt pain radiating across the ages, and realised in that moment that that pain wasn't mine." Recognising that pain brought a sense of freedom. "My depression became not me. I was liberated for the first time," she says. She took off her eye mask, looked at her guide and said, "I'm surprisingly unbroken."

This gave her a new sense of distance and separateness from the psychological distress that consumed her for decades: "A space was created between me and my depression; I no longer felt held prisoner," she says. Instead of retreading the same ground over and over, it's as if "there's a fresh bed of snow, and you can start new paths, there are new options. In fact, that whole slope is an option now. Which way do you want to go next?"

This image of a fresh bed of snow reflects what Carhart-Harris and Nutt theorise is going on in the brain. In their earlier study of people with treatment-resistant depression, participants had brain scans before and after taking psilocybin, which showed the drug had a significant impact on particular networks, turning off the brain circuits of depression, Nutt says.

Carhart-Harris explains that when people develop depression, they build up protective defences to try and fight off the anxiety, fear and pain. "It's a hibernation, a disconnection from the world, and that becomes self-reinforcing," he says. It's as if the person can only retread the same footsteps in the snow; they are stuck, ruminating and repeating the same behaviour that doesn't help – in depression as in anorexia, alcoholism and OCD among other disorders.

Psilocybin, these scientists think, helps by stimulating the type of serotonin receptors in the brain called 5-HT2A – different from the type stimulated by SSRIs. These 5-HT2A receptors are found in the cortex. Carhart-Harris describes the cortex as "the aspect of the human brain that is uniquely expanded, relative to our closest evolutionary neighbours".

The cortex is associated with species-specific functions like mind-wandering, imagination and abstract thinking. These receptors seem to be linked to plasticity – that is, to neurological change. "Psychedelics come in and free everything up, it's a window of opportunity to think and behave in a different way, like a psychological rebirth afforded by this blast of plasticity," says Carhart-Harris. It's like a fresh layer of snow falling, so instead of retreading old footsteps, a person can ask, as Leonie did, "which way do I want to go next?" ➲

The therapy room is designed to be a safe and relaxing environment

THERE'S AN APP FOR THAT

Plasticity means change in the brain – which can be positive or negative – so the trial's therapeutic aspect is crucial, says Carhart-Harris: "When you twin plasticity with care and compassion from your guide, promoting that in yourself, when you bring that to the experience and an intention to heal and open and let go – that's the healing process." But not everyone taking psilocybin illegally will do it like this. That's why Carhart-Harris and his team are launching a new app in April, called *MyDelica*. As evidence for psilocybin's impact on mental health is building, more people are using it recreationally, even though it's still illegal to be in possession of the drug. While study participants are carefully screened and attended to by therapists in a safe environment, users in the wild are not. This concerns Carhart-Harris: "I know that will come with risks, because I know the potency of psychedelics," he says.

MyDelica does not encourage or promote use of psychedelics but provides advice, such as having a sober guide with you, for those who are already taking them. "It's an attempt to de-risk what's happening now with the scaling-up of use – like a safety net," he says.

But it is not just that: by asking *MyDelica*'s users questions about their psychological history and their trips, Carhart-Harris hopes to get rich, deep data on people taking psychedelics in all sorts of contexts. "It really enhances the science because we can get bigger data than we can in expensive controlled studies, and we can address different questions," he says. In controlled studies, people with a history of psychotic disorders are screened out; in the real world, they don't screen themselves out. Carhart-Harris hopes this app will improve understanding of potential dangers. After all, an

"I don't believe psychedelic therapy is the cure for everything; I just think it is a powerful potential treatment option"

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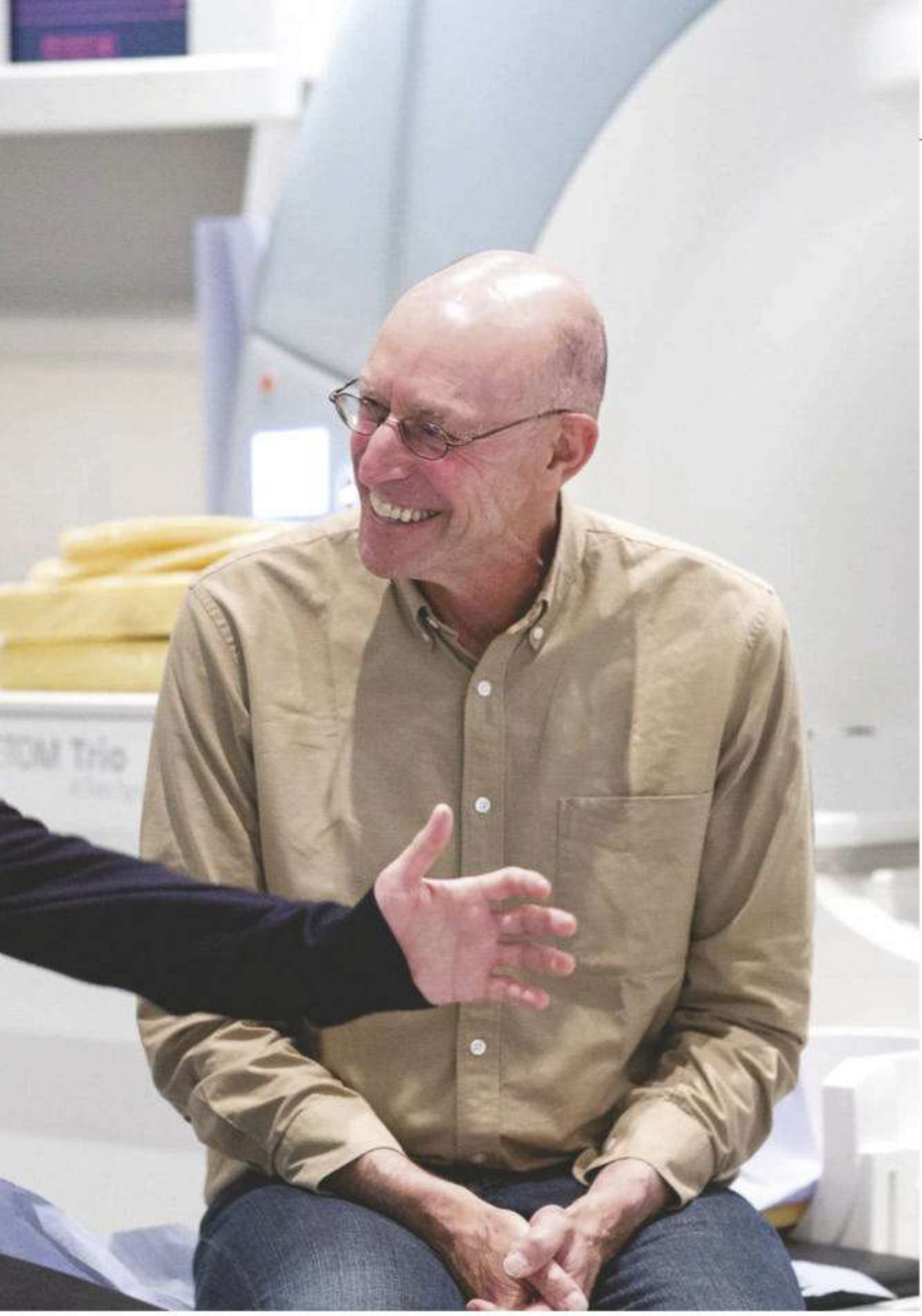

analysis of 346 self-reports by psilocybin users in February 2020 found that taking multiple doses of psilocybin in one session, or combining it with other substances, was linked with long-term negative outcomes, and in some cases the use of mushrooms in high doses was linked to medical emergencies.

Carhart-Harris is hopeful that this year, psilocybin will be accepted as a mainstream mental health treatment. He cites influential figures in academic psychiatry, along with consultants and advisors for Big Pharma companies, who have begun working with psychedelic medicine start-ups. These experts include Guy Goodwin, who is the former head of the European College of Neuropsychopharmacology and emeritus professor of psychiatry at the University of Oxford; and former head of the American Psychiatric Association Paul Summergrad, who is now the Dr Frances S Arkin Professor and chairman of psychiatry at Tufts University.

Carhart-Harris also mentions the Drug Policy Reform Group, a lobby group annexed to the Conservative Party, in which "there are quite active, vociferous people wanting to see change in drug policy". But how long will it be before Big Pharma get involved? "I'd be very surprised if they're not taking this really quite seriously," Carhart-Harris says. The mental healthcare company COMPASS produced the psilocybin used in his trial, and is also running a study for 216 patients with treatment-resistant depression, with results expected at the end of this year.

When I ask COMPASS co-founder Dr Ekaterina Malievskaia how long she thinks it will take for psilocybin to become a mainstream treatment, she says, "We're just moving as fast as possible, but not faster." She estimates three to five years from now.

Carhart-Harris is clear that psilocybin should not replace antidepressants, which do help some patients. "I don't believe psychedelic therapy is the cure for everything; I just think it is a very powerful potential treatment option," he says. "There is reason to be hopeful about treating your and your loved ones' mental illnesses."

There is a problem, however, and it's quite a big one. Psilocybin is still classified as a Class A illegal substance. Nutt has been investigating the therapeutic potential of illegal drugs for 40 years, and he sounds optimistic that things are beginning to change. "At least people like you are writing articles. Frankly, 10 years ago you probably wouldn't have been allowed to; it would've been seen as too controversial and provocative. So I think the fact that we're having an open discussion is truly, probably, the greatest thing we've achieved."

At the time of writing and publishing this piece, Carhart-Harris and his team are preparing the results of their gold-standard experiment for publication, which we plan to report on in a future issue.

In studies, Dr Robin Carhart-Harris (left) has seen success in using psilocybin to treat depression. He is hopeful that it will soon be accepted as a mainstream treatment

WHAT'S NEXT?

Leonie was convinced she had been in the escitalopram arm of the trial. Although the trip was powerful, she says, "I didn't have the textbook experience. I did not turn into a panther in some Amazonian forest, lose all sense of self or not know where my arms were. I was able to get up halfway through to go to the bathroom." But after the study was completed, she found out she'd had the high dose of psilocybin. Then things went, in her words, spectacularly wrong. Stresses piled up: unemployment, financial insecurity, Brexit, a ruptured appendix. And then the country went into lockdown. Her depression returned and she went back on short-term antidepressants to stabilise her. "And then… I came off them. This is the longest I've been unmedicated since my early 20s," she says. It is still a struggle, but she is "really feeling the feelings and getting through it, I have come out of this stronger and psychologically more resilient".

It's not that the psilocybin cured her, she says, but "I'm building on that idea that I'm not broken, that I can do this. It just takes practice, because being human is a bit messy. Every time I face the fear and come through – it really feels like that's my healing." SF

by MOYA SARNER
(@moyasarner)
Moya is a freelance writer and editor.

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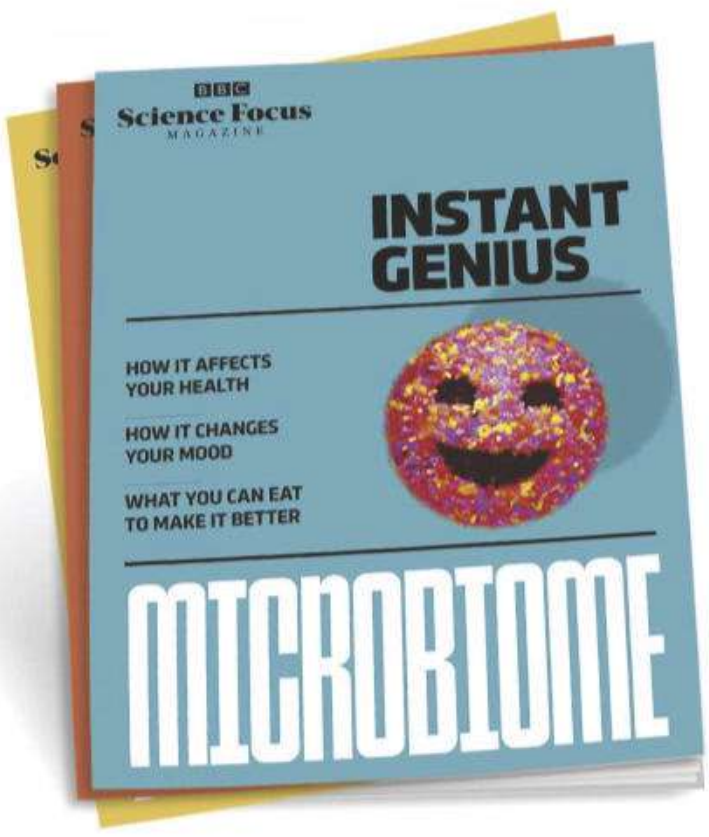

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... I LOOK LIKE A PANDA. HOW CAN I GET RID OF THE BAGS UNDER MY EYES?
... WOULD DINOSAURS HAVE GOT EVEN BIGGER IF THEY WEREN'T WIPED OUT?
... HOW DOES SOLAR ENERGY ACTUALLY WORK?
... WHY DO ROAST POTATOES STAY SO HOT FOR SO LONG?
... WHAT DAY OF THE WEEK DID THE BIG BANG HAPPEN?
... HOW BIG WOUL D A SPIDER HAVE TO BE BEFORE IT WAS UNABLE TO STICK TO THE WALL?
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KATY WILKINS, ABERDEEN

DOES CRACKING YOUR KNUCKLES CAUSE ARTHRITIS?

Our joints contain synovial fluid, a sac of liquid which acts as a lubricant, protecting bones from grinding against each other. When someone cracks their knuckles, they increase the space in the joint, causing bubbles of gas (think oxygen, nitrogen and carbon dioxide) to form in the fluid. It's the popping of these bubbles that make the cracking noise.

While it may sound worrying, there isn't actually much evidence to suggest this is dangerous – or increases the risk of getting arthritis. The most important risk factors for developing arthritis are family history, age, gender, joint injury, and lifestyle elements such as smoking and obesity.

It is true that people with arthritis sometimes find their joints crack, but this is because their cartilage has already been damaged. Cracking isn't usually the most common symptom of arthritis, either.

Although there are isolated reports of self-injury caused from cracking knuckles, such as sprained ligaments, these are very rare. You're much more likely to harm yourself by cracking joints in your spine and neck, which are surrounded by important blood vessels.

All in all, if you want to stop someone cracking their knuckles, you need to give a better excuse than worrying about their arthritis odds. ***NM***

DEAR DOCTOR...

HEALTH ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I LOOK LIKE A PANDA. HOW CAN I GET RID OF THE BAGS UNDER MY EYES?

Noticed that your eyes look like you've joined a COVID-secure Fight Club? You're not alone. Dark circles are an extremely common concern and, although not life threatening, may have an impact on emotional wellbeing.

The skin around the eye is thin and delicate, covering dark blood vessels and the muscle responsible for moving your eye lid. The dark colour can shine through the thin skin making the area appear darker.

Dark circles, or periorbital hyperpigmentation, have many causes including genetics, allergies, excess skin pigment deposits, ageing, anaemia, hormones, stress, and – of course – lack of sleep. There may be multiple factors at work, each requiring different treatments.

First, one needs to identify the cause before selecting the appropriate treatment. If, for instance, excessive skin pigmentation is to blame, you can help prevent further skin pigment deposits by applying sunscreen.

Cold tea bag compresses might also be useful. Although there is limited research that caffeine works to diminish dark circles, it can narrow the blood vessels and stimulate circulation. Plus, antioxidants, which can be found in green and black tea, have been shown to improve skin health and help prevent ageing.

If all else fails, destressing, getting enough sleep (and using a good concealer!) may help. ***SO***

JOSHUA IRWANDI, LEEDS

WOULD DINOSAURS HAVE GOT EVEN BIGGER IF THEY WEREN'T WIPED OUT?

What might have happened if that asteroid missed? Huge dinosaurs would have likely persisted. In fact, as Earth's temperature has decreased since they roamed, it's possible that – like other animals in colder conditions – dinosaurs would have got bigger.

It's important to remember here that dinosaurs were already massive. For instance, *Tyrannosaurus rex* was the largest pure predator that ever lived on land: it was the size of a double-decker bus, about 13 metres

long and weighing eight tonnes. Some long-necked sauropods like *Argentinosaurus* and *Patagotitan* were more than 30 metres (100 feet) long and weighed in excess of 60 tonnes – heftier than a Boeing 737. They were the biggest animals to ever walk Earth.

Palaeontologists have long wondered why dinosaurs got so large in the first place. Early scientists suspected it might be related to the physical environment: maybe gravity was weaker during the Age of Dinosaurs, or the atmosphere was swamped with oxygen. Yet we now know this was not the case: dinosaurs were big for their own intrinsic, biological reasons. The largest sauropods, for example, had a perfect combination of features that allowed them to supersize. Their long necks gave them access to a never-ending buffet of plants other animals couldn't reach. They had efficient lungs that took in more oxygen than mammal lungs. And those lungs were connected to air sacs that cooled their bodies.

Although they died when the Chicxulub asteroid hit 66 million years ago, it's likely these sauropods were already close to their biological limit. Any larger and it's possible they wouldn't have been able to move, breathe, or hold up their bodies.

But while this is speculation, one thing is clear: if huge dinosaurs survived today, big mammals like elephants or rhinos wouldn't have the space to co-exist. Mammals would still be in the shadows. ***SB***

GETTY IMAGES, SCIENCE PHOTO LIBRARY ILLUSTRATIONS: DANIEL BRIGHT

DANIEL VALENTINE, KENT

IF WE DON'T DESTROY IT, WHEN WILL THE WORLD COME TO AN END?

Although likely to kill many (or all) inhabitants on our planet, an enormous asteroid or comet impact would not have the energy to destroy Earth. Nor would the explosion of a powerful supernova within a few light-years. However, orbital instabilities in the Solar System may eventually lead to a catastrophic collision between Earth and one of the other terrestrial planets – Mercury, Venus or Mars. Yet the possibility of that happening is only about 1 per cent over the next five billion years or so.

The most likely scenario for the total annihilation of Earth? Being engulfed into the Sun as it transforms into a 'red giant' star. As the Sun's thermonuclear fuel, hydrogen, becomes depleted in its core, our star's outer envelope will begin to expand. In this phase of its evolution, the Sun will lose a significant amount of mass, meaning Earth's orbit will also expand. However, current theory suggests the new orbit won't be large enough for the Earth to escape interaction with the lower atmosphere of the expanding Sun. This means Earth will likely still be vaporised by the growing star.

But don't worry, this scorching destruction of Earth is a long way off: about 7.59 billion years in the future, according to some calculations. Even if our planet somehow survives and remains in orbit around the bloated red giant Sun, Earth's natural orbital decay means it would merge with the dead Sun's remnant. Eventually, anyway: this fate would occur in about 100 billion billion years. Not bad considering the Universe is only around 13 billion years old now. ***AG***

DAVID REED, NORFOLK

HOW DOES SOLAR ENERGY ACTUALLY WORK?

The Sun radiates a phenomenal amount of light and heat energy in our direction. In fact, the amount of solar energy hitting Earth's surface in just two hours would be enough to cover all of our energy needs for an entire year.

There are two key ways of capturing and using this energy from the Sun: solar panels (photovoltaics), which convert light into electricity, and solar thermal power, which transforms the Sun's energy into heat.

Inside a solar panel you'll find a neat arrangement of solar cells, each around the size of a coaster, made of two thin slices of material (usually silicon), with opposing electrical charges. As the Sun shines on the cell, photons (minuscule packets of light energy) knock electrons off the silicon atoms, in what's known as the photoelectric effect. The resulting flow of electrons forms a small electrical current in each cell.

Another way of capturing the Sun's energy is converting it into

QUESTION OF THE MONTH

ELLIS SMITH

WHAT CAUSES PEOPLE'S PERSPECTIVES TO CHANGE SO MUCH ONCE THEY BECOME PARENTS?

For many parents, when their first child is born, it's the first time in their lives that their number one priority shifts from themselves to another person. And this little person happens to be extremely cute, but also hopelessly vulnerable and needy. It's a profound change that requires a monumental shift in perspective.

Thankfully, as parents we seem to have evolved to anticipate and adapt to our new responsibilities at a neural level. In 2017, a team of neuroscientists at Universitat Autònoma de Barcelona scanned the brains of pregnant women during and after pregnancy and found reductions in the amount of grey matter in areas of the brain that are involved in so-called 'social cognition' – that is, taking the perspective and thinking of the needs of another person.

A reduction in grey matter might sound like a negative, but it's actually a sign of increased brain efficiency. This is because suboptimal connections between neurons are pruned back (a similar process happens during adolescent brain development). Moreover, the greater the grey matter shrinkage, the more signs of healthy attachment the mothers showed.

It's not just new mums who experience brain changes. In 2014 a research group at Emory University found that when fathers looked at pictures of their young children, their brains showed heightened activity in regions associated with empathy and reward, as compared with non-fathers. The change seemed to be related to hormonal shifts – on average, the dads had lower levels of testosterone and higher levels of oxytocin, a hormone that's involved in social emotions.

Bottom line: if you've ever seen a parent laughing and cooing with their snotty bundle of joy and wondered how they can see any appeal, remember their outlook has been helped along by some rather useful brain tweaks. ***CJ***

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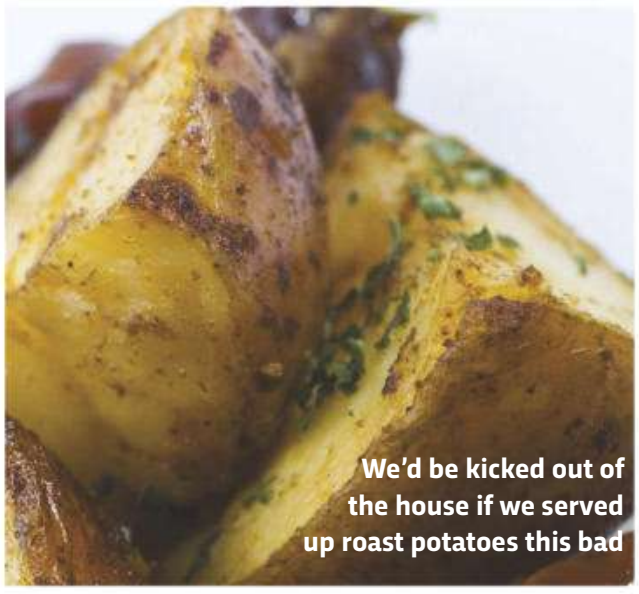
heat. Concentrating solar-thermal power plants, for instance, use mirrors and lenses to reflect and focus sunlight to heat water or other liquids. The resulting heat is used to provide hot water to homes and businesses, or to drive a turbine to generate electricity.

The downside of solar power? It can only be generated during the day. This means that it needs to be used alongside other energy sources – or stored – in order to provide a steady supply of electricity day and night.

However, as a clean, versatile and increasingly affordable form of renewable energy, solar power is set to take the world by storm. Solar panels currently produce just 2.7 per cent of the world's electricity, but our total capacity to generate solar power is expected to more than triple in the coming decade. ***AFC***



We'd be kicked out of the house if we served up roast potatoes this bad

SARAH FULLERTON, LONDON

WHY DO ROAST POTATOES STAY SO HOT FOR SO LONG?

It's mostly to do with the fatty, starchy crust that acts like an insulating layer. First, pre-boiling a potato causes its starch granules to absorb water and swell until carbohydrate molecules seep out to create a kind of thick gel. The high temperature in the oven then drives off moisture, causing the gelatinised starch on the outside of the potato chunks to form a crispy crust, trapping the heat inside. The fat from the baking tray also collects in cracks and crevices and strengthens the heat-keeping structure. ***ED***

GETTY IMAGES X2 ILLUSTRATIONS: DANIEL BRIGHT

ASTRONOMY FOR BEGINNERS

HOW TO SPOT LEO

WHEN: MARCH, APRIL AND MAY

Spring is a great time to find Leo, as the constellation is visible almost every night during March, April and May. The constellation is easy to identify because of the backwards question mark pattern created by the stars that make up the lion's face and front legs. Plus, three bright stars form a triangle that makes up the other end of the lion, its tail and back legs.

The easiest way to find Leo is by using the pattern of stars (known as an asterism) called the Plough or Big Dipper. At this time of year, the Plough will be high in the sky's northern hemisphere.

Within the Plough lie two 'pointer stars' named Merak and Dubhe. These stars can be used to point in the direction of the North Star (Polaris) but we can also use them to find Leo.

Once you've found the Plough, imagine the asterism is a pan, with a slightly bent handle. Merak and Dubhe are the two stars that make up the edge of the pan furthest away from the handle.

If the pan looks upright to you (with the handle coming out the pan's top), the pointer star on the bottom will be Merak. Follow Dubhe to Merak and continue in that direction and you'll reach the backwards question mark, also known as the Sickle, in Leo.

If you're uncertain whether you've found Leo, just check its surroundings. Leo sits between Gemini (which can be recognised by its bright stars Castor and Pollux) and Arcturus, a bright star in the constellation Bootes. You can find Arcturus by following the arc of the Plough (see diagram). ***AB***

PAD SCALON

HOW BIG WOULD A SPIDER HAVE TO BE BEFORE IT WAS UNABLE TO STICK TO THE WALL?

Some spiders can stick to walls because their feet are covered in tiny, flexible hairs that create an attractive force with a dry surface. In theory, there could be spiders as large as cats scaling walls, but they would need to have really enormous, broad feet.
This seems unlikely, as evolution has never produced a body plan like this. Plus, there are other constraints that limit a spider's body size, such as its inefficient respiratory system. *HP*

DILEEP BAGNALL, LANCASHIRE

WHAT DAY OF THE WEEK DID THE BIG BANG HAPPEN?

Simply put: we don't know. We estimate when the Big Bang happened by extrapolating backwards from observations, using cosmological theory. The current uncertainty in that estimation (currently 13 billion years) is about 20 million years – nowhere near accurate enough to pinpoint a 24-hour period.

To complicate things further: time passes differently in different places. The 'age of the Universe' is based on the way time flows on average, but for people near a big mass like a planet – or those moving with a different-from-average speed – time will pass differently. This means counting backwards day-by-day from different parts of the Universe will leave you with different answers. ***JB***

TOP TEN DEADLIEST CREATURES

(TO HUMANS, ANYWAY)

1 MOSQUITOES **725,000**

2 HUMANS (HOMICIDES ONLY) **400,000**

3 SNAKES **138,000**

4 DOGS (RABIES) **59,000**

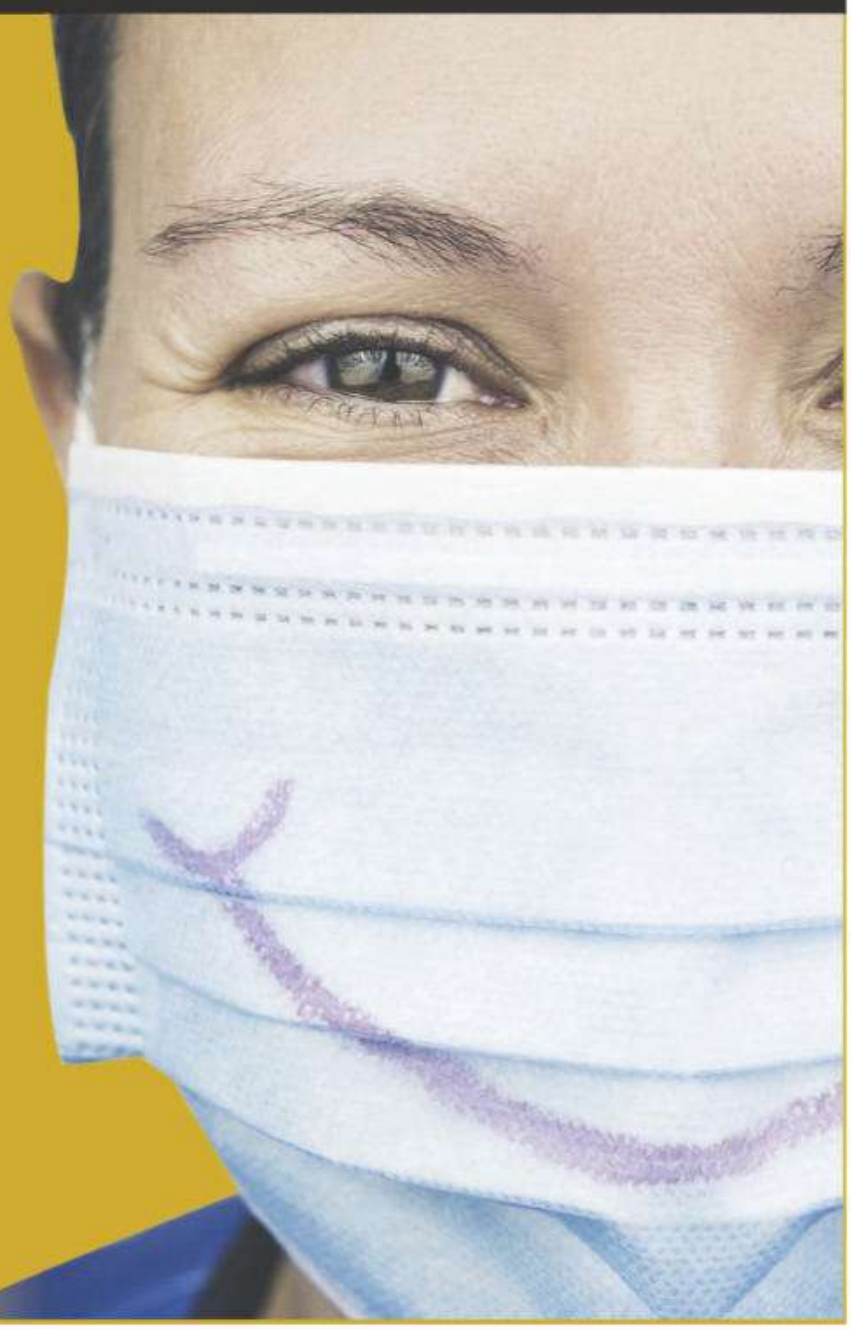
Note: all figures are human deaths per year

GETTY IMAGES X13

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

COULD BEING HAPPIER HELP US FIGHT INFECTIOUS DISEASES?



We've all heard the saying 'laughter is the best medicine'. And there might be something in this idiom: numerous studies have shown that people who report greater happiness tend to have better medical outcomes.

For instance, a 2017 study at the University of Nottingham tested the effect of mood on 138 pensioners receiving the normal flu jab. Those that felt happy on the day of the vaccination went on to produce more flu-fighting antibodies. Earlier work at Yale University and the University of Florida has also shown that your mood affects the activation of genes that fight disease.

But does happiness cause good health, or is it the other way around? After all, it could be that people who have robust immune systems naturally have higher levels of other mood-improving brain chemicals as well.

There is a possible evolutionary explanation here. Humans evolved as social creatures that cooperate in groups to secure food and protect themselves from wild animals. We were happier with a close network of friends and family because this improved our survival chances. But closely socialising groups are also breeding grounds for respiratory infections such as flu and colds, so we would have needed to increase the activity of the genes that fight these diseases.

For lonely outcasts, however, infectious disease was less of a problem, and genes that help recover from physical injury may have been prioritised instead. ***LV***

5
ASSASSIN BUGS
(CHAGAS DISEASE)
10,000

6
SCORPIONS
3,300

7
CROCODILES
1,000

8
ELEPHANTS
600

9
HIPPOS
500

10
LIONS
200

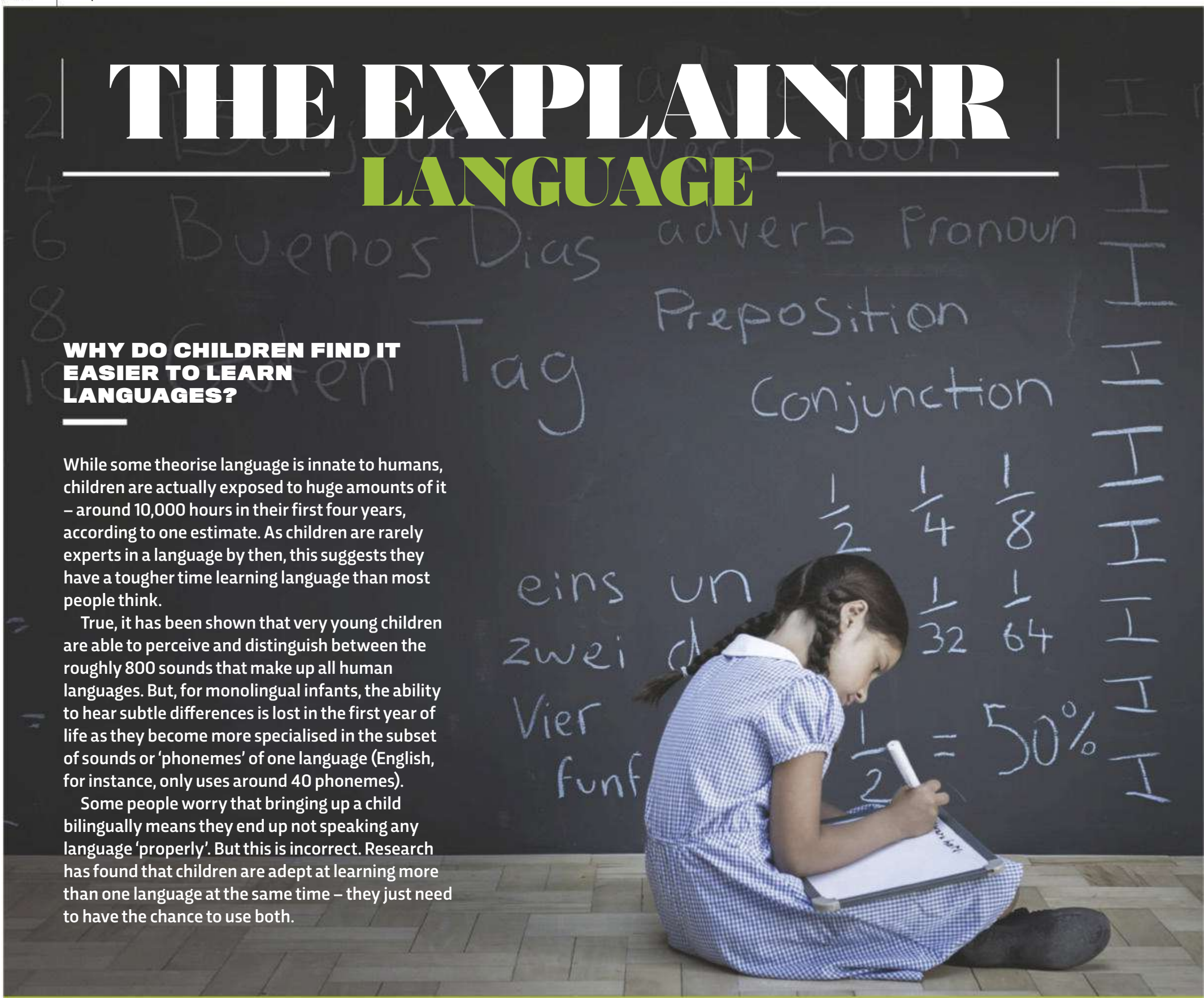
THE EXPLAINER
LANGUAGE

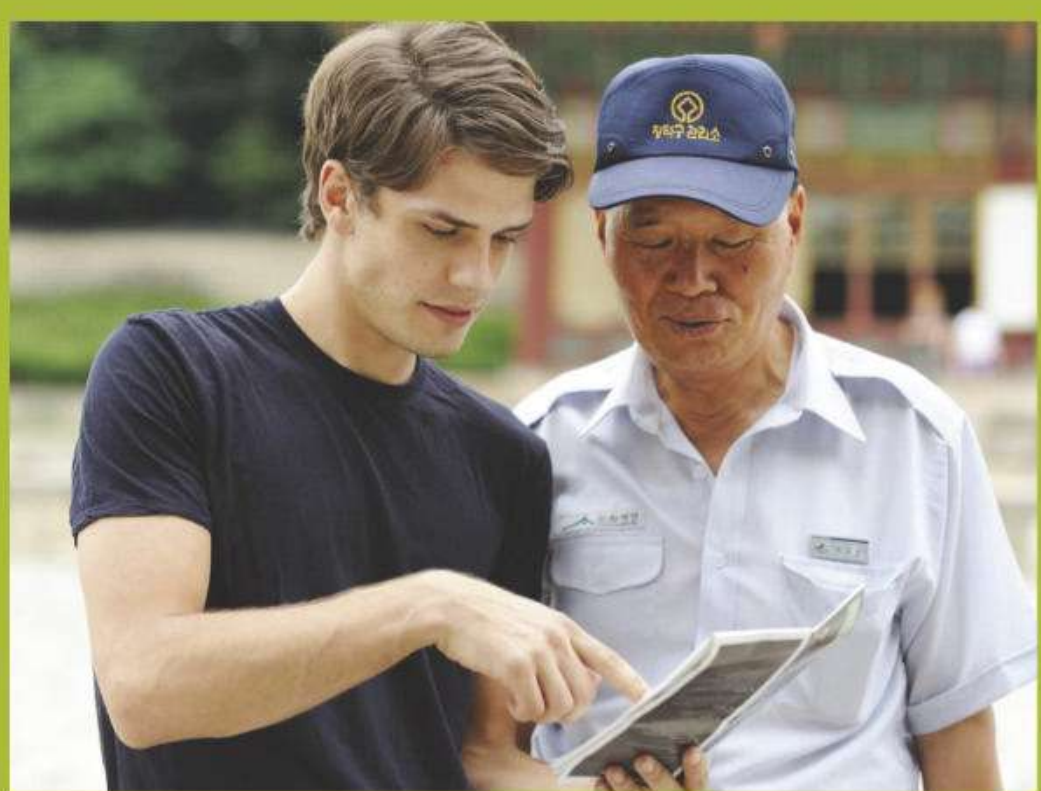
WHY DO CHILDREN FIND IT EASIER TO LEARN LANGUAGES?

While some theorise language is innate to humans, children are actually exposed to huge amounts of it – around 10,000 hours in their first four years, according to one estimate. As children are rarely experts in a language by then, this suggests they have a tougher time learning language than most people think.

True, it has been shown that very young children are able to perceive and distinguish between the roughly 800 sounds that make up all human languages. But, for monolingual infants, the ability to hear subtle differences is lost in the first year of life as they become more specialised in the subset of sounds or 'phonemes' of one language (English, for instance, only uses around 40 phonemes).

Some people worry that bringing up a child bilingually means they end up not speaking any language 'properly'. But this is incorrect. Research has found that children are adept at learning more than one language at the same time – they just need to have the chance to use both.





HOW LONG DOES IT TAKE TO MASTER A LANGUAGE?

Estimates range from 400 to 2,000 hours. But it really depends on who is learning and their reasons – research shows those who *want* to learn will pick up the language more effectively than people being *told* to learn.

It's little surprise studies have suggested that being bilingual can help you learn a new language. But why? This could be as bilingual people realise that there is no intrinsic link between a word and its meaning.

Some linguists have also theorised there are differences between brains of polyglots (people who speak more than one language) and monolinguals (those who speak only one). However, the neuroscience behind this isn't clear: researchers are still not in full agreement whether different languages are stored and accessed together or separately in the brain.

WHAT WILL THE MAIN LANGUAGE OF THE FUTURE BE?

Today, with an estimated two billion speakers, English is the largest language if we include native and non-native speakers, but Chinese is the largest if we only include native speakers (almost one billion). However, when we refer to Chinese in this way, we mean the written script, which is the same for all varieties of Chinese; the spoken varieties are different and speakers of one cannot necessarily communicate with speakers of another.

Overall, with English being the language of science, the internet and much academic research, it is likely to remain an important language in the future.

However, there's no guessing if it will be *the* language of the future – or how many languages there will be. Currently, 40 per cent of the world's estimated 7,000 languages are endangered, having less than 1,000 speakers. But there are also many linguistically diverse nations, such as Papua New Guinea, whose population speaks over 800 languages. Similarly, about 700 languages are spoken in Indonesia.

GETTY IMAGES X2, ALAMY X3

WHAT IS THE HARDEST LANGUAGE TO LEARN?

People are keen to say that certain languages (think Russian, Arabic or Japanese) are harder to learn. However, it's all pretty subjective – you'll have a natural neurological preference to languages close to your own. This happens especially when there are lots of cognate words – that is, words from different languages that have the same etymological origin, such as 'brother' in English and 'Bruder' in German.

However, languages with vastly different phonetics will be harder to process. For example, languages such as Thai, Chinese or Vietnamese use tones to distinguish lexical or grammatical meaning – basically, the intonation of words can change their meaning. For example, the word 'da' in Chinese can mean 'to hang over something', 'to answer', 'to hit' or 'big' depending on the tone.

But of course, if you already speak a tonal language, learning another tonal one presents fewer problems.

WHAT ARE THE BEST WAYS OF LEARNING A LANGUAGE?

The main key is time. You need time to learn a language (hundreds of hours, ideally) and then you need more time to use it. Practice is essential; it needs to be regular and frequent. Numerous studies have found that being immersed in a language is the best way to learn – not simply learning words and grammar. Reading magazines, watching TV and chatting to native speakers also solidifies this learning in your brain.

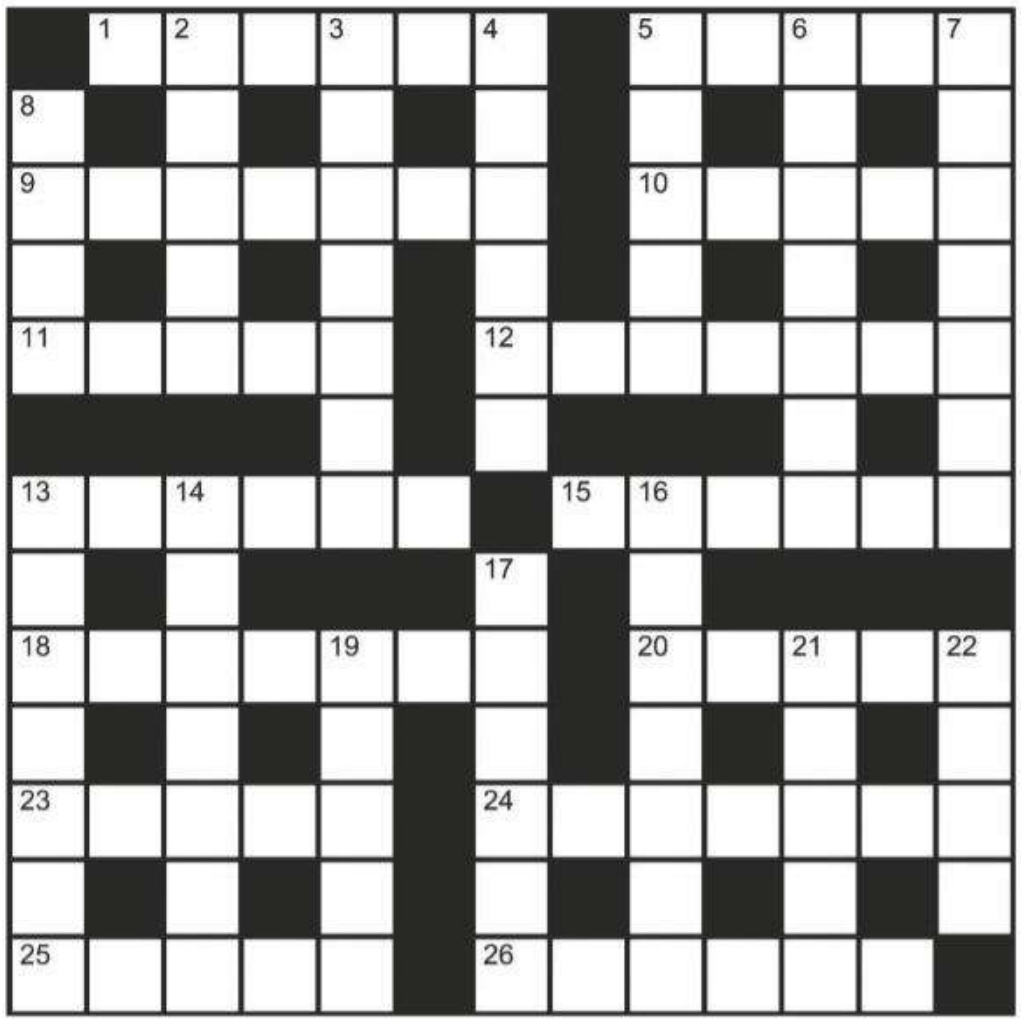
Unfortunately, no conclusive research has identified a best time of day to learn. Quite simply, you may function better in the morning, others later in the day. What is more important is not being scared to speak – some research suggests adults who over-analyse may struggle picking up the subtle rules of a language. Remember: it's not essential that you sound like a native speaker. Making yourself understood is all that matters.

by PROF NATALIE BRABER

Natalie teaches language acquisition and psycholinguistics. She is also the author of Pit Talk *(£4.99, Bradwell Books).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Plan a series of lectures (6)
5 Family is vital stuff (5)
9 Corrupt place spices arrangement at last (7)
10 Match of rare quality (5)
11 Please leave, taking a stand (5)
12 Communist chief is a colourful character (7)
13 Dog in the evening sun (6)
15 Wished to be hunted by the police (6)
18 Understood American historian (7)
20 Exercise is able to provide nourishment (5)
23 Difficult, with nothing to stockpile (5)
24 Ruin entrance to seaside resort (7)
25 Green field on faraway borders (5)
26 Left one receptacle outside case (6)

DOWN

2 Fertile patch for a group (5)
3 Drive back concerning sign of life (7)
4 Complete space with flag (6)
5 Money for a cob, say (5)
6 Luxurious work, composing tune with largo opening (7)
7 Misled and led dude astray (7)
8 Spots cane has been broken (4)
13 New latches for bag (7)
14 Feline wearing new coat gets a piece (7)
16 Dress in a quiet pearl ensemble (7)
17 Within novellas, I move an author (6)
19 Wanted dynamics to include a toy (5)
21 Stupid cars, terribly singular (5)
22 One editor's requirement (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

READY FOR LAUNCH

See the final preparations being made to the James Webb Space Telescope.

NASA/JPL

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A SCIENTIST'S GUIDE TO LIFE

HOW TO LOOK AFTER YOUR TEETH

BRUSH. FLOSS. REPEAT. BRUSH. FLOSS. REPEAT. THIS MONTH, WE ASK DENTIST **HANNAH WOOLNOUGH** HOW BEST TO MANAGE YOUR DENTAL HEALTH

REGULAR CHECK-UPS HAVE BEEN MISSED DURING THE COVID CRISIS...

… So it's time to think about booking an appointment, especially if you're a heavy drinker, a smoker, or someone with problems who used to visit the dentist regularly. If you're at all worried, talk to your dentist. Dental surgeries are COVID-secure and it's important to catch serious problems early when treatments are more effective.

MORE PEOPLE ARE GRINDING.

Anxiety associated with the COVID lockdowns is causing more people to grind their teeth. If it's happening during the day, you can try to stop yourself. If it's happening at night, a mouthguard can help, as can a botox injection – talk to your dentist about it.

BRUSH TWICE A DAY...

… And clean between the teeth at least once a day with floss or interdental brushes. The most important brush is the one just before you go to bed, so only drink water after that. Also, always wait for an hour between consuming anything acidic – like fizzy drinks or citrus fruits – and brushing your teeth, or you'll risk damaging the enamel.

PAY ATTENTION WHEN YOU BRUSH.

Watch yourself in the mirror and be systematic. Make sure you brush every surface (outside, inside, biting surfaces) and go right to the gum edges as this is where the plaque does the most damage.

ELECTRIC IS BEST.

Bamboo brushes may be green, but manual brushes don't clean that well. I recommend using an electric toothbrush with a timer and a pressure sensor so you know you're brushing for the right amount of time and not pressing too hard. Some companies make recyclable electric toothbrush heads, and some dental surgeries collect and recycle brushes, heads, tubes and packaging. You can find them online.

MAKE SURE YOUR TOOTHPASTE CONTAINS FLUORIDE.

Fluoride in toothpaste is totally safe and proven to help protect teeth from decay. There are lots of 'alternative' toothpastes on the market, but take care. Toothpastes that contain charcoal can be gritty and are potentially damaging because they're abrasive.

IT'S ILLEGAL FOR NON-DENTISTS TO OFFER TEETH-WHITENING TREATMENTS.

If you want whiter teeth, either use a whitening toothpaste, which will remove surface staining and lighten them a little, or go for professional tooth whitening. A dentist will do all the proper checks and choose the formulation that's right for you. How white you like them is up to you, but there's a limit to how far you can go without cutting your teeth down and covering them in porcelain. Just don't go to a beautician, and be aware that although you can buy products online, the formulations will be weak and won't do much.

IF YOU WANT TO KNOW WHETHER YOUR BREATH SMELLS...

… Ask someone you trust. It's sometimes difficult to know if your breath smells because you smell it all the time. Coffee and smoking don't help, but good dental hygiene can. Brush regularly and stay hydrated.

SENSITIVITY IS OFTEN CAUSED BY OVERBRUSHING.

It can cause wear to the tooth surface and recession of the gums. Acids and abrasive toothpastes also don't help. Toothpastes formulated for sensitive teeth can help, but they all have different chemical structures, so try a few and find what works for you. SF

HANNAH WOOLNOUGH *is a practising dentist and is the British Dental Association's Chair of English Council.* ***Interviewed by Dr Helen Pilcher.***

NEED TO KNOW...

1

Switch from a manual toothbrush to an electric one. Manual brushes just don't clean very well.

2

Ask your dentist about recycling your toothbrushes and toothpaste tubes. Some surgeries will offer this service.

3

Don't brush your teeth straight after drinking your morning glass of fruit juice – you risk damaging the enamel.

ILLUSTRATION: MATT HARRISON CLOUGH

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